BY ORDER OF THE SECRETARY OF THE AIR FORCE

AIR FORCE OCCUPATIONAL SAFETY AND HEALTH STANDARD 48-9

1 AUGUST 1997

Aerospace Medicine

RADIO FREQUENCY RADIATION (RFR) SAFETY PROGRAM

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(Lt Col Don Jordan)
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Certified by: HQ AFMOA/SG2
(Maj Gen Charles H. Roadman II)
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The criteria in this standard are the Air Force's minimum occupational health requirements. A program is established in this standard to prevent possible harmful effects to personnel from exposure to potentially hazardous levels of RFR. This standard applies to all US Air Force organizations, including all US Air Force Reserve and Air National Guard on Federal Service. Major commands (MAJCOM), direct reporting units (DRU), and field operating agencies (FOA) supplement this standard when additional or more stringent safety and health criteria are required refer to Air Force Instruction (AFI) 91-301, *Air Force Occupational and Environmental Safey, Fire Protection and Health (AFOSH) Programs*, for instructions processing supplements or variances. Report conflicts in guidance between this standard, federal standards, or other directives through MAJCOM, DRU, or FOA surgeons to: HQ AF Medical Operating Agency (HQ AFMOA/SGOE), 110 Luke Avenue, Room 400, Bolling AFB DC 20332-7050.

This AFOSH Standard contains the same PELs used throughout industry as instructed by Department of Defense Instruction (DODI) 6055.11, *Protection of DoD Personnel from Exposure to Radiofrequency Radiation and Military Exempt Lasers*, February 21, 1995. It applies to all Air Force military and civilian personnel (including foreign nationals) and to all sources of RFR owned or operated by the US Air Force, or under Air Force control. The Permissible Exposure Limits (PELs) of this standard do not apply to patients who are undergoing diagnostic or therapeutic procedures when RFR application is specifically prescribed by a physician, e.g., diathermy during physical therapy treatments, electromagnetic imaging, etc. The PEL does, however, apply to patients who may be exposed incidentally during the medical procedure. Control measures at least as stringent as those recommended by the DODI and the American National Standards Institute/Institute of Electrical and Electronics Engineers (ANSI/IEEE) C95.1-1991, IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic

Fields, 3 kHz to 300 GHz, April 27, 1992, are implemented by this standard. Refer also to National Council on Radiation Protection and Measurements (NCRP) Publication No. 86, No. 119, and American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLVs) Booklet for additional information on RFR. Technical assistance in applying this standard can be obtained by contacting the Armstrong Laboratory (AL/OERS) located at Brooks AFB, TX, DSN 240-3179 or (210) 536 3179.

SUMMARY OF REVISIONS

This document is substantially revised and must be completely reviewed.

Chapter 1

RESPONSIBILITIES

1.1. Secretary of the Air Force.

1.1.1. Office of the Assistant Secretary (Acquisition)(SAF/AQ). Ensures that Air Force laboratories and Special Program Offices (SPOs) address the issues of health and safety early and throughout the Research, Developement, Test and Evaluation (RDT&E) cycle and obtains measured personnel hazard data for all emitters at the earliest possible time in the cycle for inclusion into applicable Technical Orders (TOs).

1.1.2. Deputy Assistant Secretary of the Air Force (Environment, Safety and Occupational Health)(SAF/MIQ). Provides oversight for all Air Force policy related to Environment, Safety and Occupational Health.

1.2. Air Staff. All Air Staff elements will ensure their activities are conducted in a manner consistent with the spirit and intent of this standard, the DODI 6055.11, and ANSI/IEEE C95.1-1991.

1.2.1. The Surgeon General (SG):

1.2.1.1. Establishes policy for the control of RFR in Air Force workplaces and environments.

1.2.1.2. Establishes RFR personnel exposure standards and criteria.

1.2.1.3. Acts as the approval authority for waivers of protection standards and control procedures.

1.2.2. Air Force Safety Center (HQ AFSC):

1.2.2.1. Establishes safety inspection standards for RFR safety programs to ensure compliance with this standard, subject to approval by HQ US Air Force/SG.

1.2.2.2. Implements policy and inspection standards for safety programs associated with the non-biological hazards of RFR-producing systems and equipment, e.g., electro-explosive ordinance detonation, accidental fuel vapor ignitions, and electromagnetic interference hazards.

1.2.3. Air Force Inspection Agency (HQ AFIA). Implements programs to assess or inspect compliance with the requirements contained in this standard.

1.3. HQ Air Force Materiel Command (AFMC).

1.3.1. Plans, programs, and budgets for research relating to the biological effects of RFR, the health and safety of RFR workers, and the protection of the general public. Addresses the issues of health and safety early and throughout the Research, Development, Test and Evaluation (RDT&E) cycle.

1.3.2. Develops and implements policy and procedures to ensure that required personnel hazard data for emitters is measured at the earliest possible time in the acquisition cycle and is made available to the appropriate agency.

1.3.3. Provides information to using commands concerning the adequacy of RFR hazard protective devices, materials, and engineering control measures.

1.4. Human Systems Center (HSC). The HSC will, through the:

1.4.1. Armstrong Laboratory, Occupational and Environmental Health Directorate, Radiofrequency Radiation Division (AL/OER, Brooks AFB):

- Provide research, consultation and assistance on the biological effects of RFR.
- Maintain information on ways to measure, evaluate, and control occupational exposures to RFR.
- Maintain technical expertise in RFR technology and new developments which may affect safety in Air Force operations.
- Provide guidance to Bioenvironmental Engineers on the use and application of commercially available safety products. Such products include those designed to protect personnel from RFR exposure, to detect the presence of RFR fields, or to measure exposure levels.
- Assist the US Air Force Surgeon General's office in establishing policy on the use and application of safety devices on Air Force Installations.
- Maintain specialized measurement equipment necessary to monitor and record RFR emissions, perform field measurements, and evaluate work environments for potential hazards to the health and safety of Air Force employees and the general public.
- Conduct occupational health and environmental safety surveys of RFR facilities and emitters to identify areas in excess of the PEL, and to determine the type of control measures required.
- Send the Director, HQ Air Force Medical Operations Agency (AFMOA), USAFE, PACAF and each MAJCOM copies of reports, studies, and other information relating to RFR safety.
- Work with other AFMC laboratories and other services to evaluate any unique or unusual RFR safety issues.
- Help solve specific operational RFR problems.
- Recommend RFR personnel exposure limits to the HQ AFMOA.
- Maintain a repository containing the nominal characteristics of Air Force owned and operated RFR emitters to assist installation level personnel with the inventory and identification of potentially hazardous systems. Ultimately this repository should be made available via the world wide web or similar structure in order to facilitate use by customers.
- Maintain an official repository containing pertinent records of personnel overexposures that were found to be five times the PEL or greater.
- Provide consultation on RFR facilities evaluation, RFR exposure control, medical surveillance, and biomedical research programs.

1.4.2. US Air Force School of Aerospace Medicine, Department of Bioenvironmental Engineering (USAFSAM/BE) will:

- Provide formal training programs for medical personnel to ensure they are proficient in conducting the necessary RFR hazard assessments and measurements, and are knowledgeable about the current issues involving RFR and the known bioeffects associated with exposure.
- Work closely with the researchers and consultants located at AL/OER to ensure that instruction provided to trainees is based on the most current applicable scientific findings, and in keeping with the most current Air Force policies.
- Obtain guidance and assistance from AL/OER when developing RFR course curriculums to ensure the accuracy and applicability of information conveyed to the students.

1.4.3. Armstrong Laboratory, Aerospace Medicine Directorate, Clinical Sciences Division (AL/AOC, Brooks AFB) will:

- Provide consultant examinations in ophthalmology and dermatology.
- Develop methods to evaluate occupational injuries resulting from exposures to RFR.
- Recommend medical surveillance requirements to HQ AFMOA/SGP.

1.5. US Air Force in Europe (USAFE). Through resources of 601 Med Squadron/SGB, gives advice and aid similar to that tasked to Armstrong Laboratory (AL/OER) (paragraph 1.4.1).

1.6. Major Commands (MAJCOM), Direct Reporting Units (DRU), and Field Operating Agencies (FOA).

1.6.1. Ensure operation and maintenance activities implement measures to prevent personnel exposure to RFR in excess of the limits prescribed in this standard.

1.6.2. Request specific RFR exposure criteria or standards not contained herein from HQ USAF/SGP, Director of Professional Services.

1.6.3. Contact AL/OER for guidance and assistance in resolving personnel RFR hazards.

1.7. Host Wing, Center, and (or) Division Commander. Host Wing, Center, and (or) Division Commander will:

1.7.1. Through the Bioenvironmental Engineer (BEE), support integrated implementation of this standard throughout the wing, center or division.

1.7.2. Support BE in their efforts to ensure compliance with this standard to ensure wing compliance.

1.7.3. Ensure implementation of this standard by government contractors through appropriate procurement action. Contracts should state who is responsible for occupational safety and health surveillance of the contract employees working on Air Force facilities with government equipment. Whenever possible, new contracts should include compliance requirements of this AFOSH standard.

1.8. Medical Treatment Facility (MTF) Commander. The Medical Treatment Facility (MTF) Commander will The MTF commander's responsibilities are carried out, through the appropriate agency as detailed in the following paragraphs:

1.8.1. Bioenvironmental Engineering Flight (BE) will:

- Maintain a proficient level of knowledge, training and experience in assessing RFR radiation hazards in the workplace, performing required measurements, and responding to health issues raised by workers, base residents, and the general public.
- Act as the central focal point and local expert on matters relating to RFR hazards and bioeffects, with the support and assistance of Armstrong Lab personnel.
- Be familiar with the requirements of this standard and application of the appropriate PELs in order to run an effective health and safety program.
- Assist unit commanders and shop supervisors in the development of RFR safety awareness training programs, particularly in the area of bioeffects, exposure incident reporting, and identification and control of hazardous areas in the workplace.

- Review and evaluate the adequacy of existing baseline survey data for each RFR environment on the base.
- Evaluate all RFR emitters capable of producing levels in excess of the PELs for periods of time that could result in personal overexposures. Document the hazard evaluation in the appropriate facility case file.
- Conduct RFR health hazard evaluations when new systems, operations, or modifications occur in the workplace to include the following:
- Identify controlled environments where the limits in table 2.1 apply.
- Identify uncontrolled environments where the limits in table 2.2 apply.
- Establish restricted access to areas in controlled and uncontrolled environments which exceed the applicable PEL.
- Recommend engineering controls, posting requirements, and administrative controls as necessary.
- Evaluate all requests for personal protective equipment and warning devices and control its issuance and use, where appropriate. Protective equipment should only be issued where engineering controls are not feasible or appropriate.
- Advise local commanders, during contingency operations, regarding the potential for personnel injuries from RFR emissions during combat operations.
- Investigate all alleged or suspected overexposures according to the instructions in paragraph 3.5 of this standard. Complete the final report of investigation for submission according to attachment 2. Notify and coordinate with Armstrong Laboratory, RFR Division, Sources and Measurements Branch (AL/OERS), as needed, and provide copies of the final documentation for evaluation and possible inclusion in the RFR Exposure Repository.
- Provide the MAJCOM BEE, AFMOA/SGPA, and AL/OERS initial notification of a suspected RFR exposure.
- Notify PH of any RFR incidents which may require investigation. Provide the PH office of the BE findings from investigations and the final exposure determination.

1.8.2. Public Health Flight (PH) will:

- Work closely with BE in investigating RFR incidents, and provide medical surveillance feedback to BE.
- Prepare and distribute AF Form 190, Occupational Illness/Injury Report, and additional documentation as appropriate for all incidents of alleged personnel overexposure to RFR as outlined in AFI 48-101, Aerospace Medicine Operations, and this standard.
- Coordinate investigations of suspected or known overexposures to personnel with the installation ground safety staff, provide a copy of the AF Form 190, and advise BE of medical diagnostic results.
- Ensure medical follow-up examinations specified by the occupational medicine consultant at AL/AOC are conducted for persons identified as having been overexposed to RFR.

1.9. Unit Commanders. Unit commanders will:

1.9.1. Establish a unit RFR safety awareness training program.

1.9.2. Ensure shop supervisors responsible for the operation of potentially hazardous RFR emitters develop a unit radiation safety awareness training plan to aide in the implementation of the unit training program.

1.9.3. Establish procedures for workers to report suspected overexposures to the responsible supervisor, and to BE. Supports BE investigative efforts and reconstruction of exposure incidents. Ensure these procedures are incorporated into the unit safety awareness training plan.

1.10. Supervisor. The supervisor will:

1.10.1. Ensure workers under their supervision are aware of and follow the safety procedures outlined in this standard, equipment technical manuals, and unit safety awareness training program

1.10.2. Prepare an RFR safety awareness training plan to provide initial training for newcomers and refresher training for system operators, maintenance personnel, and other workers assigned to duties in controlled environments.

1.10.3. Ensure the safety awareness training plan includes the following items:

- Location of potentially hazardous emitters operated by the unit.
- Areas that could exceed the radiation levels in table 2.1.
- Control procedures necessary to avoid exposures in excess of the Permissible Exposure Limit (PEL).
- Actions to be taken in the event of a suspected or actual RFR overexposure.
- Overview of the bioeffects that result from overexposure to RFR.

1.10.4. Coordinate RFR survey and measurement activities with command and supervisory personnel and ensure these individuals are kept informed of the status of all such activities, particularly during investigations of suspected or actual overexposures.

1.10.5. Inform BE and request a risk assessment survey for each new RFR system prior to operation. Notify BE of any physical or operational changes that could increase the power density of the field generated by the emitter.

1.10.6. Ensure work areas identified by the BEE as hazardous RFR areas are clearly posted.

1.10.7. Ensure proper corrective actions are accomplished according to AFI 91-301 whenever a risk assessment code is assigned to a hazardous RFR situation.

1.11. Individual.

1.11.1. Follows procedures for safe work given in this standard, equipment TOs, manuals, and unit OIs.

1.11.2. Follows procedures established by the supervisor to ensure safe working conditions.

1.11.3. Ensures required warning signs and safety devices are in place and functional before beginning work.

1.11.4. Promptly reports any suspected overexposure and any unsafe work condition to his or her supervisor.

Chapter 2

REQUIREMENTS

2.1. Permissible Exposure Limits (PELs).

2.1.1. The PEL is that exposure value to which an individual may be exposed without exhibiting damaging biological effects. PELs are derived from the recommended exposure levels in ANSI/IEEE C95.1-1991, which serves as a consensus standard developed by representatives of industry, scientific communities, government agencies, and the public. These values have been based upon a whole-body specific absorption rate (SAR) of 0.4 watts per kilogram (W/kg), and incorporates a safety factor of 10 below a SAR of 4.0 W/kg, which is the threshold for the occurrence of potentially deleterious biological effects in humans.

2.1.2. PELs are expressed in terms of measurable field parameters as a convenient correlation to the SAR. These field parameters include root-mean-square (rms) electric field (E) and magnetic (H) field strengths, their squares, or the plane-wave equivalent power densities (S) associated with these fields, and peak electric field strengths. Induced and contact current limits that can be associated with exposures to such fields are also established.

2.1.2.1. Sections A in tables 2.1 and 2.2, refer to time-averaged exposure values obtained by spatially averaging S, or the mean squared E and H values, over an area equivalent to the vertical cross-section of the human body (projected area). In the case of partial-body exposure, or non-uniform fields, these PELs (Section A) may be exceeded, but must comply with the partial body exposure limits listed in Sections D, tables 2.1 and 2.2. The PELs may also be exceeded if it can be shown that the SAR limits described in paragraph 2.9.3 are not exceeded. This may be accomplished through SAR calculations or measurements utilizing human tissue equivalent material. Base level Bioenvironmental Engineers may contact the Armstrong Lab Consulting Function for guidance when evaluating exposure incidents to determine if the PEL may be exceeded. The PELs may not be exceeded under any circumstances for exposure cases involving the head, eyes or testes.

2.1.2.2. For near-field exposures at frequencies less than 300 MHz, the applicable PEL is given in terms of rms E or H values. For convenience, the PELs also may be expressed in terms of plane-wave-equivalent values as shown by the S values in parentheses for the E and H fields, respectively, at frequencies less than 100 MHz.

2.1.3. There are no special RFR exposure limits for pregnant females. Any RFR environment that is safe for the mother is also safe for the developing embryo or fetus.

2.1.4. No practice shall be adopted or operation conducted involving planned exposure of personnel to RFR levels in excess of the applicable PEL.

2.2. PEL Averaging Periods.

2.2.1. PELs in table 2.1, Section A, refer to values averaged over any 6-minute period for frequencies less than 15 GHz, and over shorter periods for higher frequencies (10 seconds at 300 GHz). The PELs in table 2.2, Section A refer to values generally averaged over any 6-minute or 30-minute period for frequencies less than 3 GHz. For certain frequency intervals, the averaging period will vary as a function of frequency as shown in tables 2.1 and 2.2, Sections A.

2.2.2. For an exposure duration less than the averaging period, the maximum permissible exposure level, is PEL [Tavg/Texp], where Texp is the exposure duration in that interval expressed in the same time units as Tavg.

2.3. Controlled Environment PELs. The controlled environment PELs, given in table 2.1, are given as a function of frequency and were based on a SAR of 0.4 W/kg. These limits were developed to control human exposures to electromagnetic energy at radio frequencies ranging from 3 kHz to 300 GHz, and to limit the localized SAR occurring in the feet, ankles, wrists, and hands of personnel due to exposure to such fields or contact with objects exposed to such fields. PELs are given in terms of rms electric (E) and magnetic (H) field strengths, equivalent plane-wave free space power densities (S), and induced currents (I) in the body. Controlled environment exposures include the following:

- Exposure that may be incurred by personnel who are aware of the potential for RFR exposures conjoined with their employment or duties.
- Exposure of other cognizant individuals.
- Exposure that is the incidental result of passage through such areas where analysis shows the levels may exceed those given in table 2.2, Part B, but do not exceed those values in table 2.1, Part B.

For example, an administrative assistant who works in the administrative office of the communications squadron on the flightline, and is aware of the presence of RFR in the work environment, would be subject to the Controlled Environment PELs of table 2.1. This individual should be made aware of the areas where RFR is present during the initial awareness training process, and should be advised as to where safe levels can be exceeded. Thus, the administrative assistant has accepted the potential risk of exposure that may be incurred during the performance of their normal duties. If the same individual lives near an Air Force Radar facility, the residential environment occupied by the assistant and the individual's exposure while in the residential environment would be controlled by the PELs given in table 2.2.

Table 2.1. PELS for Controlled Environments.

Frequency Range(f) (MHz)	Electric Field (E) (V/m)	Magnetic Field (H (A/m)	Power Density(S) (mW/ cm^2) (E,H)	Averaging Time (Tavg in min) (E, H, S)
A. RFR Fields.				
0.003 - 0.1	614	163	(10^2, 10^6)	6
0.1 - 3.0	614	16.3/f	(10^2, $10^4/f^2$,)	6
3 - 30	1842/f	16.3/f	(900/f2, $10^4/f^2$,	6
30 - 100	61.4	16.3/f	(1.0, $10^4/f^2$,)	6
100 - 300	61.4	0.163	1.0	6
300 - 3000			f/300	6
3000 - 15000			10	6
15000 - 300000			10	$616000/f^{1.2}$

Frequency Range (f) (MHz)	Maximum Current Through Both Feet (mA)	Maximum Current Through Each Foot (mA)	Current (mA)
B. RFR Induced and Contact Current Restrictions.			
0.003 - 0.1	2000f	1000f	1000f
0.1-100	200	100	100

Frequency Range (f) (MHz)	Peak Electric Field (E) (kV/m)	Peak Power Density Pulse for Pulse Durations < 100 msec (mW/cm^2)
C. Pulsed RFR Fields (apply only when there are less than 5 pulses within the averaging time).		
0.1 - 300000	100	(PEL)(T_{avg})/(5)(pulse width)

Frequency Range (f) (MH^2)	Peak Value of Mean Squared Field (V^2/m^2 or A^2/m^2)	Equivalent Power Density (mW/cm^2)
D. Partial-Body Exposures.		
0.1 - 300	< 20E^2 or 20H^2	
300 - 6000		< 20
6000 - 96000		$< 20(f/6000)^{0.25}$
96000 - 300000		40

2.4. Uncontrolled Environment PELs. Uncontrolled environment exposures can occur in areas where individuals would have no knowledge or control of their exposure. These locations would include living quarters or workplaces where there are no expectations that the exposure levels may exceed those shown in table 2.2. In uncontrolled environments where individuals unfamiliar with the phenomenon of induced RFR currents may have access, precautions should be taken to limit induced currents to values not normally perceptible to individuals, as well as prevent the possibility of RFR burns.

Table 2.2. PELS for Uncontrolled Environments.

Frequency Range(f) (MHz)	Electric Field (E) (V/m)	Magnetic Field (H) (A/m)	Power Density (S) (mW/cm^2) (E,H)	Averaging Time (T_{avg} in min) (E, S)	(H)
A. RFR Fields.					
0.003 - 0.1	614	163	(102, 106)	6	6
0.1 - 1.34	614	16.3/f	(102, 104/f^2)	6	6
1.34 - 3.0	823.8/f	16.3/f	(180/f^2, 104/f^2)	f^2/0.3	6
3.0 - 30	823.8/f	16.3/f	(180/f^2, 104/f^2)	30	6
30 - 100	27.5	$158.3/f^{1.668}$	$(0.2, 9.4 \times 10^5/f^{3.336})$	30	$0.0636f^{1.337}$

100 - 300	27.5	0.0729	0.2	30 30
300 - 3000			f/1500	30
3000 - 15000			f/1500	90000/f
15000 - 300000			10	$616000/f^{1.2}$
Frequency Range (f) (MHz)	Maximu Current Through Both Feet (mA)		Maximum Current Through Each Foot (mA)	Current (mA)
B. RFR Induced and Contact Current Restrictions.				
0.003 - 0.1	900f		450f	450f
0.1-100	90		45	45
Frequency Range (f) (MHz)		Peak Electric Field (E) (kV/m)	Peak Power Density Pulse for Pulse Durations < 100 msec (mW/cm2)	
C. Pulsed RFR Fields (apply only when there are less than 5 pulses within the averaging time).				
0.1 - 300000		100	$(PEL)(T_{avg})/(5)(\text{pulse width})$	
Frequency Range (f) (MHz)		Peak Value of Mean Squared Field (V^2/m^2 or A^2/m^2)	Equivalent Power Density (mW/cm^2)	
D. Partial-Body Exposures.				
0.1 - 300		$< 20E^2$ or $20H^2$		
300 - 6000			4	
6000 - 96000			f/1500	
96000 - 300000			20	

NOTE:

Measurements to determine adherence to the PEL shall be made at distances of at least 20 centimeters (cm) or greater from any object.

2.5. Induced Current Limits. (Section B of Tables 2.1 and 2.2).

2.5.1. Guidance is provided for limiting the RFR induced currents (averaged over any 1 second) in the human body for free-standing conditions (no skin contact with metallic objects); and under conditions of grasping contact with metallic bodies to limit the maximum RFR current through an impedance equivalent to that of the human body.

2.5.2. The controlled environment induced body current limits will prevent localized SAR in the ankles or wrists from exceeding 20 W/kg. For uncontrolled environments, where individuals would not be aware of the existence of RFR currents, the values are set at levels that are not normally perceptble to individuals. In general, between 3 kHz and 100 kHz, the perception threshold is related to a tingling or prickling sensation; while between 100 kHz and 100 MHz, the perception threshold is related to a sensation of heat or warmth. Under some conditions, touching conductive objects in the vicinity of a radiating RFR antenna could result in a flow of RFR current of sufficient magnitude to be painful or that may produce a burn at the point of contact.

2.5.3. Evaluation of induced RFR currents will generally require a measurement to determine the RFR current flowing to ground through the feet of the individual, or the RFR current flowing through the hand in contact with a conductive surface. Measurement equipment required for these types of surveys is not generally available at base level. Paragraph 3.3.4 contains guidance on how to identify systems that may require further evaluation using induced and contact current measurement devices. For systems generating frequencies between 0.003 and 100 MHz, contact AL/OERS, RFR Consulting Function for detailed guidance and measurement capabilities.

2.6. Pulsed Peak Field Limits. (Section C of Tables 2.1 and 2.2).

2.6.1. Peak power exposure limitations are provided for pulses in the frequency range of 0.1 to 300,000 MHz, where each pulse is less than 100 milliseconds (msec) and there are no more than 5 pulses in the time averaging period. Those limits are given to prevent unintentionally high exposure and to preclude high specific absorption for decreasingly short widths of pulses. If there are more than 5 pulses during any time period equal to the averaging time, or if the pulse durations are greater than 100 msec, the time-averaged S should not exceed the PELs given in Section A of tables 2.1 and 2.2.

2.6.2. For exposure to RFR pulses in the frequency range of 0.1 to 300,000 MHz, exposure is limited by either a peak (temporal) E field of 100 kV/m for each pulse or in terms of a peak power density value (S) for each single pulse, whichever is more limiting. For high frequencies and longer pulses, peak S will be more conservative.

2.6.3. The limitation on RFR fields under pulsed conditions, (less than 100 msec), means that the PEL as averaged over any 100 msec is reduced by a factor of five, and a maximum of five such pulses is permitted during any period equal to the averaging time. For example, in the microwave region for exposure to a single pulse, the specific absorption over any 6-minute period is limitd to 28.8 J/kg per pulse (spatial average) with a maximum of five such pulses (i.e., (5)(28.8 J/kg) = 144 J/kg), which is equivalent to a SAR of 0.4 W/kg over a 6-minute period).

2.7. Partial Body Exposure Limits. (Section D of Tables 2.1 and 2.2).

2.7.1. Implicit in the PEL definition of a whole-body averaged SAR of 0.4 W/kg for a controlled environment and 0.08 W/kg for an uncontrolled environment, is the assumption that spatial peak SARs may occur that exceed the whole-body averaged values by a factor of more than 20 times. The values provided in Section D of tables 2.1 and 2.2 allow for equating substantially non-uniform field exposure or partial-body exposure to an equivalent uniform field exposure. The BEE should consider the values given for partial body exposures when the exposure exceeds the PELs given in tables 2.1 or 2.2, and the exposure was limited to a specific part of the body, or the field was not uniformly distributed over the whole body of the individual exposed.

2.7.2. For exposure of parts of the body, the spatially averaged PELs given in Section A of tables 2.1 and 2.2 may be relaxed provided the peak value of the mean squared field strength (E and H Fields) does not exceed 20 times the square of the allowed spatially averaged values at frequencies below 300 MHz, or the equivalent S levels do not exceed the levels shown in Section D. of tables 2.1 and 2.2 as averaged over the Tavg periods given for frequencies above 300 MHz. Those rules for relaxation of the limits for partial-body exposure do not apply for exposures to the eyes. The SAR exclusion rules in paragraph 2.7.1 can still be used to show conformance to the PEL, despite localized S values above the specified whole-body average. In such cases, exposures to the eyes are limited by the basic exposure criteria of a whole-body averaged SAR of 0.4 W/kg (controlled environment) or 0.08 W/kg (uncontrolled environment), and spatial peak SARs of 8 W/kg (controlled environment) or 1.6 W/kg (uncontrolled environment) as averaged over any one gram of tissue.

2.8. PELs and Exposure Guidance for High Power Microwave (HPM) and Electromagnetic Pulse (EMP) Simulators:

2.8.1. HPM Systems. For exposures in controlled environments involving HPM narrow-band systems, the exposure limit for any single pulse or series of pulses lasting less than 10 seconds is provided in table 2.3. For uncontrolled environments, exposures shall conform with the PELs in table 2.2.

2.8.1.1. The exposure guidance given below in table 2.3 is based on HPM narrow-band systems operating within the following parameters: maximum pulse width of 10 microseconds, peak S of 0.1 to 10 kW/cm2, frequency greater than 100 MHz, repetition rate not greater than 10 pulses per second.

2.8.1.2. The exposure guidance is specific for HPM narrow-band systems and does not apply to exposure from EMP broad-band simulator systems. If the HPM system is not within those parameters, then the PELs in table 2.1 apply.

2.8.1.3. For personnel exposure to HPM in a controlled environment, the measured fluence is not to exceed the values given in Section A of table 2.3 for any single pulse or series of multiple pulses lasting less than 10 seconds. The total fluence delivered over any 6-minute period shall not exceed the values in Section A of table 2.3. In all cases, the instantaneous E field shall not exceed 200 kV/m.

2.8.1.4. If the exposure values given in Section A of table 2.3 cannot be met, then the total measured SA to the head shall not exceed 150 J/kg for any single pulse or 150 J/kg for multiple pulses in any 6-minute period.

2.8.2. EMP Simulator Systems. For exposure in controlled environments involving broad-band EMP simulators, the exposure limit is given in Section B of table 2.3. Measurements of EM Fields from broad-band EMP simulator systems require special instrumentation and techniques because of the inherent rapid rise time and the high field strengths associated with EMP. Contact Armstrong Laboratory, Radiofrequency Radiation Division for measurement and evaluation assistance.

Table 2.3. PELs for HPM and EMP Simulator Systems.

Frequency Range (f) (MHz)	Peak Electric Field (E) (kV/m)	Maximum Fluence Level in Controlled) Environments for Any Single Pulse or Series of Multiple Pulses Lasting Less Than 10 seconds Within Any 6-Minute Period (J/cm2)
A. HPM (Narrow-Band Systems)		
100 - 300	200	0.36
300 - 3000	200	3.6(f/3000)

>3000	200	3.6
Frequency Range (f) (MHz)	Peak Electric Field (E) in Controlled Environments (kV/m)	
B. EMP Simulators (Broad-Band Systems)		
0.1 - 300000	100	

2.9. Exclusions Rules for PELs.

2.9.1. The PEL values may be relaxed in the case of partial-body exposure, or by reference to the SAR exclusion rules, or the low-power device exclusion rules, as follows:

2.9.2. Partial-Body Exposure. In the case of partial-body exposure conditions from highly directional sources or from substantially non-uniform fields over an area equivalent to the body, relaxation of the PELs in tables 2.1 and 2.2, Sections A, is allowed for exposures limited to a portion of the body. Maximum values for partial-body exposure limits are in Section D of tables 2.1 and 2.2. Partial-body limits do not apply in the case of direct exposure to the eyes.

2.9.3. SAR Exclusion Rule. The PELs in Sections A of tables 2.1 and 2.2 may be relaxed by reference to SAR limits through calculations or measurements, as follows:

2.9.3.1. Controlled Environment Exclusion:

2.9.3.1.1. At frequencies between 3 kHz and 100 kHz, the PEL can be exceeded, if it can be shown that the peak rms current density as averaged over any 1 cm^2 area of tissue and over 1 second does not exceed 0.035(f) mA/cm^2 where f is in kHz.

2.9.3.1.2. At frequencies between 100 kHz and 6 GHz, the PEL may be exceeded if the exposure conditions can be shown to produce SARs below 0.4 W/kg as averaged over the whole body, and spatial peak SAR values not exceeding 8 W/kg as averaged over any one gram of tissue; except for the hands, wrists, feet, and ankles where the spatial peak SAR shall not exceed 20 W/kg as averaged over any 10 grams of tissue, and the induced body currents conform with the values in Section B of table 2.1.

2.9.3.1.3. At frequencies above 6 GHz, where body absorption is quasi-optical and body resonance considerations do not apply, the PELs may be relaxed using the time-averaged limits for partial-body exposures given in Section D of table 2.1.

2.9.4. Uncontrolled Environment Exclusion:

2.9.4.1. At frequencies between 3 kHz and 100 kHz, the PEL can be exceeded, if it can be shown that the peak rms current density as averaged over any 1 cm^2 area of tissue and over 1 second does not exceed 0.0157(f) mA/cm^2 where f is in kHz.

2.9.4.1.1. At frequencies between 100 kHz and 6 GHz, the PEL may be exceeded if the exposure conditions can be shown by techniques to produce SARs below 0.08 W/kg as averaged over the whole body, and spatial peak SARs not exceeding 1.6 W/kg as averaged over any one gram of tissue; except for the hands, wrists, feet, and ankles where the spatial peak SAR shall not exceed 4 W/kg as averaged over any 10 grams of tissue, and the induced body currents conform with the values in Section B of table 2.2.

2.9.4.1.2. At frequencies above 6 GHz, where body absorption is quasi-optical and body resonance considerations do not apply, the PELs may be relaxed using the time-averaged limits for partial-body exposures given in Section D of table 2.2.

2.9.5. Low-Power Device Exclusion. At frequencies between 100 kHz and 1.5 GHz, the PELs given in tables 2.1 and 2.2 may be exceeded under the following conditions for devices in which the radiating structure is not maintained within 2.5 cm of the body:

2.9.5.1. Controlled environment low-power device exclusion pertains to devices that emit RFR energy under the control of an aware user. That exclusion addresses exposure of the user.

2.9.5.1.1. At frequencies between 100 kHz and 450 MHz, the PEL may be exceeded if the radiated power is 7 watts, or less.

2.9.5.1.2. At frequencies between 450 and 1500 MHz, the PEL may be exceeded if the radiated power is (7)(450/f) watts, or less, where f is in MHz.

2.9.5.2. Uncontrolled environment low-power device exclusion pertains to devices that emit RFR energy without control or knowledge of the user.

2.9.5.2.1. At frequencies between 100 kHz and 450 MHz, the PEL may be exceeded if the radiated power is 1.4 watts, or less.

2.9.5.2.2. At frequencies between 450 and 1500 MHz, the PEL may be exceeded if the radiated power is (1.4)(450/f) watts or less, where f is in MHz.

2.9.5.3. At frequencies above 1500 MHz, engineering judgment should be used when granting a low power exclusion. For example, since the low power exclusion for controlled environments at 1500 MHz is 2 watts, a source of 15 GHz (10 times higher), with 20 mW (10 times lower) could also be excluded.

Chapter 3

BASE PROGRAM REQUIREMENTS

3.1. Risk Assessment. The risk assessment process involves the recognition and evaluation of the potential risk to human health. This chapter addresses the methodology for recognizing RFR hazards and for performing hazard evaluations for potentially hazardous systems. The requirements for the effective management of an installation level RFR protection program are defined herein. Questions regarding the management or implementation of an installation program requirements should be referred to the RFR Radiation Division of Armstrong Laboratory, (AL/OERS) Brooks AFB TX 78235-5324, DSN 536-1182. Assistance with electromagnetic compatibility testing or the assessment of risks associated with electro-explosive devices (EEDs) and fuel handling operations, must be referred to the 738 EIS/EEEX, 801 Vandenberg Avenue, Suite 201, Keesler AFB MS 39534-2634, DSN 597-3920.

3.2. Recognition. The recognition phase begins with baseline and annual industrial hygiene shop surveillance. All RFR transmitters owned and operated by avionics shops, communications facilities, industrial processes, and medical facilities should be identified during the regularly scheduled, on-site visits to these areas. The AF Form 2759, **Radiofrequency Radiation Emitter Survey Data**, should be completed at this time. Copies of this completed form for potentially hazardous emitters can be maintained separate of the cased files and used to develop a consolidated inventory. This can be a useful management tool for bases with large programs or unusual systems, but is not mandatory.

3.2.1. Risk Assessment Ratings. The final risk assessment rating should be assigned to each emitter upon completion of all phases of recognition and evaluation, but the process actually begins in the recognition phase. Each system should be classified according to the hazard potential it presents, then rated according to the potential risk it represents. Examples of risk ratings are provided below with hazard potential categories discussed in paragraph 3.2.2:

3.2.1.1. Low Risk. A low risk indicates the system either is not capable of producing levels at or above the PEL (low-power excluded devices), or the transmission time is too short to exceed the average power density allowed for that frequency. For example, auto mounted or hand held radar guns used for traffic control would be classified as a low risk to users and the general public. These devices cannot produce levels of energy at the PEL, so would be excluded from the inventory and assessment.

3.2.1.2. Moderate Risk. A moderate risk rating indicates the system is capable of producing power densities in excess of the PEL, but physical system controls are in place that would preclude exposure to personnel under normal operating conditions, test or maintenance procedures. Examples of such controls would include the following:

- Safety interlocks that shut the system down if beam rotation is stopped.
- Elevation interlocks that turn off transmission when the angle of the beam is lowered to ground accessible elevations.
- Dummy loaded systems, and emissions into RFR absorbers commonly called “hats”. that are accessible from the ground.

NOTE:

A real world example of a moderate risk system is the typical TACAN antenna found on almost every flying base. If the antenna rotation slows down at all from the design speed of 900 rpms, for any reason, the radiation emissions automatically shut down. Thus the system presents only a moderate risk of exposure to personnel because it can produce levels of energy above the PEL, but the interlock system must fail before any significant risk of exposure could reasonably be expected.

3.2.1.3. High Risk. A high risk rating is warranted for systems that can and do produce average power densities at or above the PELs, and these areas are accessible to personnel during normal operating conditions, or during routine test and maintenance procedures. Signs, rope barriers, cones or other control measures must be posted prior to transmitting with theses types of systems. Examples of high risk systems include some nose mounted radar on small aircraft where the beam is accessible from the ground and routinely operated in a stationary mode for maintenance or testing while other maintenance personnel are working on or near the aircraft. Interlocks may reduce the hazard potential, but care should be exercised by the surveyor in ensuring these interlocks are not routinely bypassed as a part of normal operations.

3.2.1.4. The initial information gathered during the industrial hygiene survey is crucial to the evaluation process. Once the parameters for RFR emitters have been recorded, the next step is to determine which emitters are potentially hazardous to personnel. The major factor in determining the hazard potential of a particular emitter is based on accessibility of personnel. Hazardous areas that are well above ground level, or not normally accessible to personnel, are recorded as inaccessible or climbing hazards (IH or CH) and are regarded as a lower survey priority. A detailed hazard assessment should then include the following processes:

- Review the operating parameters of the device and determine if the device is a low-power device as described in paragraph 2.9.5.
- Review past surveys of the emitter or similar systems. Case files and Armstrong Laboratory may be able to provide some previous survey data.
- Review technical orders on the systems and look for parameters and other hazard distance information.
- Perform a simple far-field calculation using the system parameters. This is a conservative estimate of the hazard distance, but is a very useful starting point in the pre-survey phase.

3.2.2. Emitter Hazard Potential. A description of the emitter hazard potential should be included on AF Form 2759 and maintained in the appropriate case file. Levels found at or above the PEL in the workplace, should be clearly defined in the case file, to include the hazard location and accessibility to personnel. One or more of the categories listed below should apply to each emitter:

3.2.2.1. Non-hazardous Emitters. RFR emitters that can be defined as low-power devices, as described in paragraph 2.9.5, are considered non-hazardous equipment, and are excluded from the PELs specified in tables 2.1 and 2.2 as long as the radiating structure is not maintained within 2.5 cm of the body. The criteria for low-power devices is based on a combination of frequency range and radiated power of the system (see paragraphs 2.9.5.1 and 2.9.5.2 for detailed information). No further evaluation or data collections are required for non-hazardous emitters. Hand-held radios, cellular telephones, etc. usually fall into the non-hazardous category, but no system may be eliminated from the evaluation process if the radiating element is maintained within less than 2.5 cm from the body.

3.2.2.2. Potentially Hazardous Emitters. RFR emitters which do not fit the criteria for low-power devices (non-hazardous emitters), and are capable of producing levels at or in excess of the PELs given in tables 2.1 and 2.2, are considered potentially hazardous. However, the degree of hazard potential varies with environmental setting, duration of transmission, operator's location, etc. During the recognition phase each emitter should be reviewed to determine the necessity and priority for performing further surveys and measurements during the evaluation phase. The use of hazard codes is no longer a requirement. Data on all potentially hazardous emitters must be maintained in the appropriate facility case file. Include all unclassified operational parameters, hazard potential descriptions, and the location of fields found to be at or in excess of the PEL. These will include, but are not limited to, aircraft-mounted radar and electronic counter-measures (ECM) systems, some in-shop radar mockups, some ground-based radar systems, certain communications systems, some medical emitters, and all industrial emitters such as heat sealers.

- Ground-level Hazard Emitters. These are systems capable of producing power density levels at or above the PEL in areas accessible to personnel at or near ground level. This can generally be determined by the location of the main beam above ground level, the size and shape of the beam, and the angle of elevation. Many aircraft-mounted radar and electronic counter-measures (ECM) systems will fall into this category. These types of systems should be the highest priority during the evaluation phase.
- Climbing Hazard Emitters. These transmitters are capable of producing levels of RFR in excess of the PEL, but only in areas that require climbing. These emitters should be evaluated to determine if, when, and where maintenance personnel may be required to climb into these areas. Even if the maintenance procedures require shutdown with manual or automatic interlocks, the potential for exposure may still exist if the controls are bypassed or failed. Exposure levels where the public may have access to the main beam should be calculated during the evaluation phase and compared to the PELs in table 2.2 to determine compliance. These systems should be the second priority on the list of systems that require further evaluation.
- Inaccessible Emitters. These are systems capable of producing levels in excess of the PEL, but only in areas not normally accessible to personnel. These systems should be evaluated to determine if maintenance procedures require entry into areas where the PEL could be exceeded. Those areas where maintenance is performed should be included in the evaluation phase of the risk assessment process, at least initially, and annually thereafter. These types of systems should be the third priority on the list of systems that require further evaluation.
- Short Duration Emitters. These systems are capable of producing levels in excess of the PEL, but the transmission time is relatively short when compared to the PEL averaging time, under normal operating conditions. Thus, the transmission time is usually too short to result in an exposure that is likely to produce a SAR greater than 0.4 W/kg. These types of systems may include hand-held radios, base stations, some airborne and ground communications systems that require manual or voice activation, etc. to transmit. Some automatic systems will transmit just long enough to retransmit a message. On-time could vary, but will probably not exceed the duration necessary to result in an exposure above the average PEL. Repair and maintenance shops where these systems are maintained should be a higher priority than routine operations when evaluating these types of systems.

3.3. Evaluation.

3.3.1. Evaluation Requirements. During this phase the emitter, its operational and maintenance environments, operational parameters and exposure potential are evaluated against the applicable PELs to determine if personnel can be exposed to levels in excess of the standard. Evaluation should include the following:

- Determine the applicable PEL for each emitter from tables 2.1, 2.2, or 2.3.
- Perform hazard distance calculations to estimate the hazard distance.
- Visit the site to determine accessibility, locations, and conditions that present potential hazards.
- Verify the conclusions drawn during the recognition phase.
- Measure to identify actual hazard locations and to define controls for these hazards.

3.3.2. Theoretical Hazard Evaluations. Theoretical hazard calculations are useful for predicting the distance at which the PEL is expected to be exceeded relative to the radiating element or antenna. This type of evaluation is complicated by many factors, but useful estimates can be made. The operating parameters from the AF Form 2759 (listed in attachment 3) must be specified adequately for the true average-radiated power from the antenna, and the resulting power density at some distance point can be calculated. For theoretical computations it is desirable to choose the parameters that result in the most restrictive, "worst case" PEL, but do not exceed the maximum rated duty factor of the transmitter. In the case of multiple sources, the contribution of each source should be considered when estimating the combined effect. Attachment 3 provides instructions for characterizing antenna fields and computing theoretical hazard distances.

3.3.3. Site Inspection Surveys. The primary reasons for inspecting the emitter site is to determine if it is accessible to personnel and to determine if power density measurements will be required. In some cases the visit will simply verify the conclusions drawn during the initial recognition and theoretical evaluation processes. Personnel should be informed to notify the BEE and installation ground safety upon occurrence of any suspected personnel exposure, radiation leakage, or changes in existing systems or operating conditions. Documentation of the findings should be accomplished in the appropriate case file.

3.3.4. RFR Measurement Surveys. Initial measurement surveys must be accomplished on systems capable of producing levels at or above the PELs unless excluded under the low-power device exclusion rules, or existing measurement survey data can be applied under local conditions.

- Other Measured Data. Measured data from surveys conducted elsewhere may be substituted for on-site measurements, only if the emitter components (transmitter and antenna), operational conditions, and system parameters are the same. An on-site inspection is required to ensure the survey data is applicable under existing environmental and operational conditions. The facility case file must clearly state the source of the measured data and findings of the on-site assessment.
- Inaccessible Systems Requirements. For systems where the beam is clearly inaccessible to personnel during normal operations, initial measurements should be performed to confirm beam inaccessibility, and to probe occupied work areas for leakage from transmitter cabinets, waveguides, cables, etc. All operating procedures and work practices must be thoroughly evaluated to ensure there are no conditions under which the beam is accessible to personnel.
- Short Duration Transmitters. If the transmission time is too short to exceed the average PEL, and is not likely to result in a peak exposure that would produce a SAR greater than 0.4 W/kg, then no

survey measurements are required. However, measurements may be desired to confirm these findings.

- Documentation Requirements. Records of surveys, reports, calculations, and control measures imposed shall be maintained for each fielded RFR emitter which is capable of exceeding the PELs in table 2.2. AF Form 2759 is a convenient means of recording most emitter information for those emitters capable of producing levels at or above the PEL. The use of antenna codes and hazard codes on the 2759 is no longer required, but the form should be augmented with a brief hazard assessment narrative summarizing the potential risks involved with the use and operation of the specific emitter. The hazard assessment narrative may include a summary of measured data collected by the BEE or from other sources, such as an Armstrong Lab Report. The exact locations where the PELs can be exceeded for both controlled and uncontrolled areas should be included in the narrative and demonstrated in a diagram or photograph. On-site measurement surveys must be conducted in all cases where there is any doubt about where personnel hazards (power densities at or above the PEL) might exist. Facilities responsible for the use and operation of emitters capable of producing levels at or above the PEL should also have an entry on the Air Force Form 2754 in the appropriate industrial hygiene.
- Measurement Techniques. Worst case operating parameters under fixed-beam conditions should be used to define the location of hazard distances <u>whenever possible,</u> unless the system has been previously measured. This is particularly important in siting new ground systems. Measurements should be conducted to determine two hazard distances, one for the controlled environment and one for uncontrolled environments. Measurement surveys of this type have proven more than worth while in situations involving a reduction in the PELs with implementation of a new standard. Many litigations can be avoided by making this simple measurement survey a matter of record. Using theoretical hazard evaluations (far field formula) to estimate the hazard distance prior to performing this type of measurement will provide the surveyor with a safe distance from which to approach the antenna. This is a long accepted method for performing RFR measurement surveys and has been practiced by bioenvironmental engineering personnel Air Force wide since the heating effects of RFR energy became known. This type of survey, if done correctly, is perfectly safe for the surveyor to perform, particularly with the probe extended in front of the body and parallel to the ground. If mission requirement, or safety interlock devices preclude making worst case measurements, then normal operating parameters should be used to identify hazardous areas. If fixed beam measurements are not possible, then an averaging module may be utilized to assess power density fields in accessible areas. RFR hazards should be evaluated using the measurement procedures and techniques recommended in IEEE C95.3-1991 (reference (g)), as basic guidance. That requirement does not preclude using other RFR measuring and evaluation methodologies. Very general guidelines are provided in the following paragraphs. For more specific guidance, refer to the IEEE Standard C95.3-1991.

3.3.4.1. Where multiple RFR emitters may be collocated in fixed arrangements, such as aboard ships or at communication sites, RFR evaluation data should include a determination of the weighted contribution from expected simultaneously operated emitters. For example, mixed or broadband fields at a number of frequencies for which there are different PELs, the fraction of the PEL in terms of E2, H2, or S incurred within each frequency interval should be determined, and the sum of all such fractions should not exceed unity. A detailed example for that type of calculation is in Appendix C of IEEE C95.1-1991 (reference (c)).

3.3.4.2. For both pulsed and non-pulsed fields at frequencies below 300 MHz, the power density, the square of the field strengths and the SARs, as applicable, are averaged over any 6-min or 30-min period. The time-averaged values should not exceed those given in table 2.1, Part A and table 2.2, Part A, or their exclusions. Note, the averaging time is a function of frequency above 15 GHz for a controlled environment and is a function of frequency between 1.34 and 3.0 MHz, and above 3 GHz for an uncontrolled environment. (The averaging time is also a function of frequency between 30 and 300 MHz for exposure to magnetic fields.)

3.3.4.3. Measurement devices to evaluate induced current and contact current levels are commercially available, but performing these types of measurements can be very problematic. Purchase of these instruments is not recommended at this stage in the developing technology. However, it is prudent to screen all systems operating between 0.003 and 100 MHz to determine if induced current or contact current limits may be exceeded. This is done simply by performing power density or field strength measurements and recording these results. Consult with AL/OERS, Consulting Function for a determination regarding the potential for exceeding these current limits around systems located on your installation.

3.3.4.4. Generally both the E and H fields must be determined for frequencies less than 300 MHz. For frequencies equal to or less than 30 MHz, assessments can only be accomplished by the independent measurement of both field components. For frequencies between 30 and 300 MHz, it may be possible through analysis to show that measurement of only one of the two field components is sufficient. For frequencies above 300 MHz, only one field component need be measured, usually the E field. The need to measure both E and H fields below 300 MHz derives from a consideration of the spatial variation in E and H field strengths in the reactive near field of an antenna. PEL boundary locations are to be established by determining the farthest distance from the radiating source that a PEL value (E or H field) can be exceeded using appropriate measurement techniques for the conditions of measurements.

3.3.4.5. Measurements to determine adherence to the recommended PEL shall be made at distances 20 cm or greater from any object. (See IEEE C95.3-1991).

3.3.4.6. Evaluation of induced RFR currents will generally require a measurement, unless the exposure situation is very simple. Many exposure conditions are complex and induced currents are not amenable to analysis. Induced currents may be measured by one or more of the following three methods:

3.3.4.6.1. RFR thermocouple-type ammeter measurements - These devices, employing thermocouple elements for the measurement of RFR currents, offer true rms detection and may be inserted directly in series with the conduction path for the current flow into the body, or exiting the body. While simple in design and use, thermocouple type ammeters have very limited tolerance for overload currents that can destroy the thermocouple element.

3.3.4.6.2. Voltage measurements--The induced current may also be determined by measuring the RFR voltage developed across a non-inductive resistor that is connected in series with the current path, as in (a). Either a broadband type of voltmeter, suitable for the frequency of the current, or a narrowband, tunable voltmeter in the form of a tuned receiver may be used to determine the voltage. The current is determined from the relation:

$$I=V/R$$

where

I = induced RFR current (A)

V = RFR voltage drop across the resistor (V)

R = impedance of the resistor (Ω)

NOTE:

Various forms of circuits making use of this basic method may be used for purposes of measuring the magnitude of the RFR current flowing from the body to ground, including the use of parallel plate electrodes connected with a resistive element upon which an individual may stand. Commercial instruments with a flat frequency response between 3 kHz and 100 MHz are beginning to become available for this purpose.

3.3.4.6.3. RFR current transformer (current probe) measurements - RFR current transformers are of the clamp-on type or the fixed window type. Either type may be used to measure the RFR current. The carrying conductor is typically placed in the window of the device and acts as the primary for the transformer. Current transformers may be used to determine the current flowing in a parallel plate electrode arrangement, as described in the previous paragraph, or in conjunction with a conductive rod probe assembly to determine contact currents that might be experienced by a person touching an object exposed to RFR fields. Generally, the current transformer requires some form of instrument to detect the output voltage from the transformer and subsequently, the current that flows through the window of the transformer.

CAUTION: In each of the three methods, an impedance equivalent to the human body at the frequency of interest must be utilized to perform the initial assessment to avoid current actually flowing through the body until after the magnitude of the field is evaluated. An antenna or phantom model may be used to measure the actual flow in a human to make an indirect measurement of the current. When selecting a human equivalent antenna or phantom model, ensure that the phantom dipole moment, surface area, and contact impedance are equivalent to those of the simulated subject. Exercise care during instrument selection since its frequency dependence will affect the measurement result. Thermocouple detectors used in some RFR ampmeters exhibit variations in response to different frequencies (commonly becoming less efficient at higher frequencies), and current transformer performance characteristics are a compromise between sensitivity and bandwidth. Meters, associated circuitry, and methodology shall be appropriate to the particular frequency and the meters shall have an averaging time no greater than 1 second. AL/OERS may be consulted to assist with equipment selection and current measurements.

3.3.5. Ancillary Hazards. Hazards not directly associated with the RFR field survey are discussed in detail in attachment 4. The surveyor must thoroughly review attachment 4 and understand the direct and indirect hazards that may be associated with the measurement of RFR energy.

3.4. Controls. Controlling hazards in the workplace is the ultimate goal of every occupational or environmental health and safety program. This fact is also true for RFR hazards. After the survey work is complete, the next step is to evaluate existing control measures, if any, and determine what is required for the protection of Air Force workers and the general public. For high risk emitters, capable of producing levels at or above the PEL in accessible areas, the types of control measures discussed in the following paragraphs are some of the more commonly used means available. These types of control measures may be recommended by the installation bioenvironmental engineer following thorough evaluation of the hazard potential, to include survey measurements. In some cases, many of these controls may already be established due to interference or other indirect or ancillary hazards.

3.4.1. Low Power Devices. No control measures are required for low-powered, non-hazardous emitters (see paragraph 2.9.5) that are excluded from the PELs in tables 2.1 and 2.2.

3.4.2. Mandatory Posting Requirements. Figure 3.1. provides an example of the approved format for RFR Hazard Warning Signs and the appropriate instructional or warning statements to be inserted on the signs in the lower half of the triangle. Specific posting requirements are given in the following paragraphs for each type of operational area.

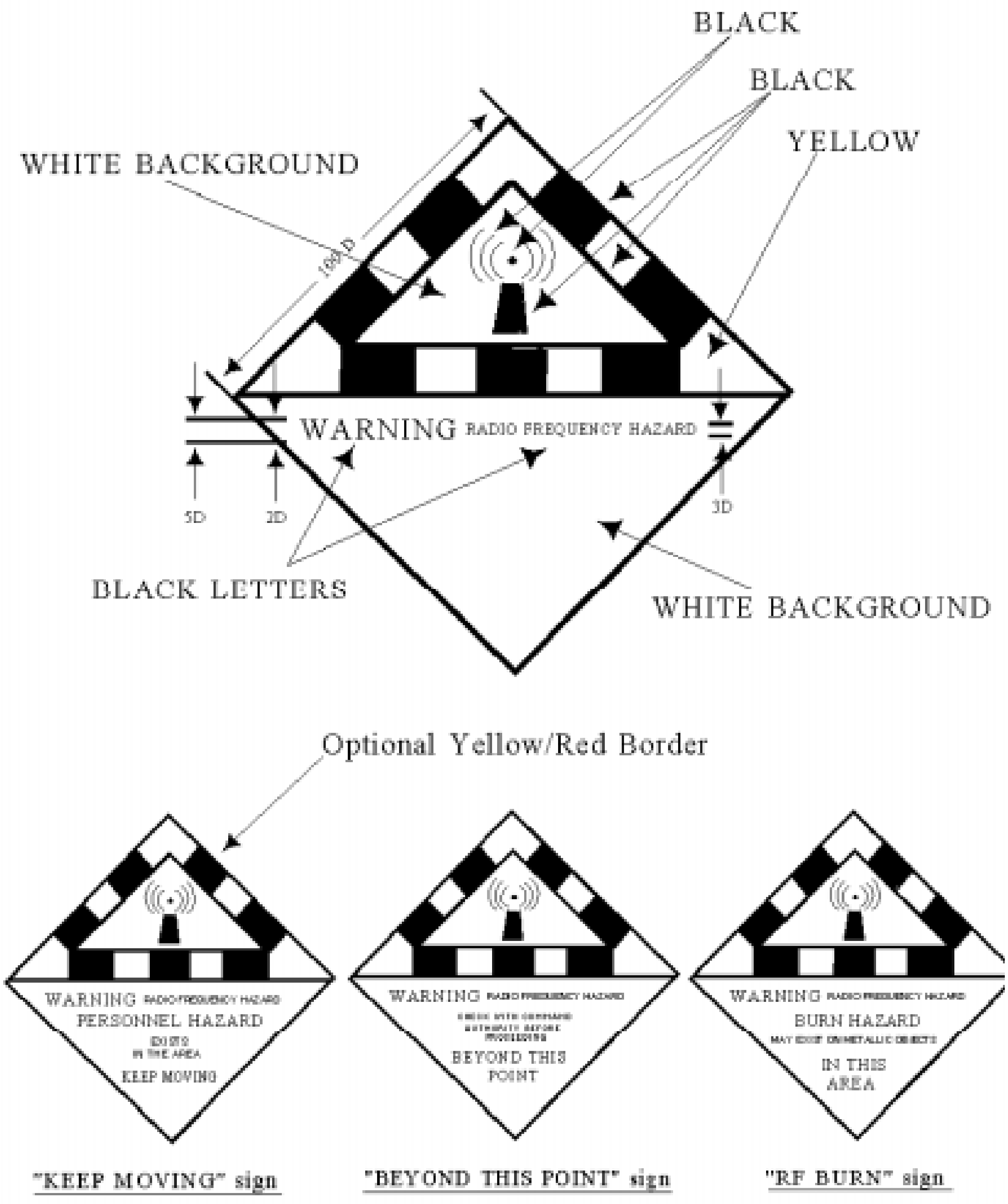
3.4.2.1. Posting Controlled Areas. RFR warning signs must be posted at all access points to areas in which levels exceed the controlled environment PELs listed in table 2.1. Warning signs should be placed where they are visible from all directions of approach.

3.4.2.2. Posting Uncontrolled Areas. Where the RFR levels exceed the uncontrolled environment PELs given in table 2.2, RFR warning signs shall be posted in areas as determined by BE.

3.4.2.3. High Level Areas. In Areas where personnel may have access to 10 times the controlled environment PELs, (see table 2.1), warning signs alone do not provide adequate protection. Other warning devices, such as flashing lights, audible signals, barriers, or interlocks, are required depending on the potential risk of exposure. The risks in such an area must be assessed by a qualified bioenvironmental engineer to include written instructions which clearly document the necessary control measures. Safety controls inherent in the equipment design, or established by other safety or measurement agencies, or by the operational group, may not be bypassed without evaluation and approval by the installation BEE.

3.4.3. Visitors to Controlled Areas. It is prudent for unit commanders and supervisors to inform guests visiting their facilities that they will be entering a controlled environment where, by definition, the power density levels beyond the entry control point could be expected to exceed those levels normally found in their private domicile, but still within the safe limits for an RFR controlled environment. Any restricted areas within the controlled environment where levels could exceed the limits given in table 2.1 must be clearly posted, and visitors should be instructed to remain outside the posted areas.

Figure 3.1. RFR Hazard Warning Sign Format.



3.4.4. Other Administrative and Physical Controls:

3.4.4.1. Cones with Warning Signs Affixed. Common orange and yellow traffic cones may be utilized to delineate the perimeter of a hazard area. Signs as described in figure 3.1 may be affixed to the cones to provide the necessary posting requirements.

3.4.4.2. Roped Off Areas with Warning Signs. Temporary or permanent areas may be posted in this manner. Temporary areas may use wooden stands utilizing a rope or chain between the stands to delineate the perimeter or to block an access point. A permanent area may use wooden or metal posts driven into the ground or cemented in place. Appropriate warning signs should be attached to the rope, posts, or chain. Signs should be visible from all directions of approach.

3.4.4.3. Fences. Metal chain link or wooden fences may be utilized to control access to hazardous areas. However, wooden fences (non-conductive) are commonly used around HF emitter sites due to the potential for metal objects to passively re-radiate RFR.

3.4.4.4. Constant Observation. Posting a qualified operator or technician to observe the illuminated area during transmissions is a physical or administrative control measure that may be implemented in instances where permanent posting or roping off an area is not feasible. Conditions of this type may occur during field deployment exercises when mobile systems must be operated, but posting requirements would compromise the location of the unit or otherwise interfere with the mission of the unit. Under those conditions, constant observation may be substituted for highly visible signs or other controls that would compromise the intended purpose of subdued paint and camouflage. However, under normal conditions, an observer may not be substituted for mandatory posting or other BEE recommended controls. Constant observation is typically used in conjunction with other control measures for added protection.

3.4.4.5. Prior Coordination. This is an administrative control measure usually implemented to prevent workers from inadvertently accessing areas that could exceed the PELs. This control establishes a procedure for maintenance personnel entering such areas to notify the controller or the operator before entering the area. Rarely, but in some cases, a similar measure may be established that requires the emitter operators to notify affected personnel prior to transmission. These situations are rare, but may be necessary in highly congested areas, especially where fuel transfer operations or explosives could be impacted. Finally, prior coordination on a busy installation may be implemented to work in both directions whereby emitter controllers or operators and maintenance personnel are both made aware of each others actions before proceeding.

3.4.5. Engineering Control Measures:

3.4.5.1. Azimuth Blanking. This is a common practice for search radars. Azimuth blanking allows operators to null transmissions when the radar is pointed at a particular range of azimuths or mechanically (or electronically) restrict the radar from pointing in a certain azimuth. Normally this is implemented to prevent ground structures from interfering with the radar, but it can also be used to prevent RFR hazards to personnel. Some systems allow azimuth blanking to be enabled and disabled by simple changes entered at a computer terminal. Close attention should be given to blanked systems during the evaluation phase to ensure the system is utilizing the azimuth blanking prescribed for that system.

3.4.5.2. Dummy Load. Dummy loads are commonly used instead of antennas to preclude free space irradiation inside the shop area. When properly connected on a bench test system, dummy loads are most effective. However, these systems occasionally experience cracks that may result in RFR leakage up to several inches from the equipment. Care should be taken during the evaluation phase to ensure workplaces utilizing dummy loads have adequate written OIs to quickly identify faulty equipment and improperly installed components. Operating instructions should include procedures for responding and reporting suspected personnel exposure incidents.

3.4.5.3. Flashing Lights. Flashing lights or audible signals are used in areas with high RFR levels.

3.4.5.4. Interlocks. These are devices that automatically switch off the RFR emissions when a door, hatch or other entry point is breached. Standard operating procedures should be written which identify all tasks that require the circumvention of safety interlock systems. These procedures should clearly document what alternative safety procedures are to be implemented when bypassing the interlock. Surveyors should pay close attention to written operating procedures during the evaluation phase.

3.4.5.5. Kill Switches or Panic Buttons. These are safety devices that are usually installed inside rooms where antennas are located and are for emergency use only. If an individual is accidentally locked inside the radome at the time of transmission, using one of these devices would immediately alert the operators, open the exit door to the antenna room and shutdown power to the system. These devices are not a first line defense against an exposure. These controls should be utilized in conjunction with other control measures to prevent personnel from being locked inside the building to begin with, such as flashing lights outside the doors, etc.

3.4.5.6. Electric Shock & Burns. Personnel should be adequately protected from electric shock and burns through the use of electrical safety matting, electrical safety shoes, or other isolation techniques. These items are specifically required for controlled areas where frequencies are below 30 MHz as electric shock and burns are the primary hazards. See paragraph 2.3 for definition of controlled environments.

3.4.6. Personal Protective Equipment:

3.4.6.1. RFR Protective Clothing. RFR shielded clothing is not acceptable as a method of protecting individuals from hazardous levels of RFR. Shielded clothing will not be used for Air Force operations.

3.4.6.2. RFR Sensors, Detectors, Alarms, Area Monitors, and Personal Warning Devices. The US Air Force Surgeon General does not advocate the use of personal detectors or area monitors in Air Force operational environments. Devices of this nature can provide a false sense of security to workers in many situations. These devices can be overly sensitive or insensitive depending upon the positioning of the emitter, sensor, and body. The wearer's body may shield the detector, causing the sensor not to alarm when needed. The human body can also enhance the field resulting in false alarms. Detection of the presence of RFR does not usually occur unless a strong field is present, in which case the wearer may already be in a field that exceeds the limitations in this standard. If the device is adjusted to be more sensitive, alarms would sound when RFR levels are well below personnel exposure limits, resulting in unnecessary consternation. Generally, if the working environment is controlled such as described by this standard, no additional warning devices are deemed necessary and supplemental warning devices provide little benefit. In cases where the environment may exceed 10 times the PEL, special needs may be addressed and evaluated through consultation with Armstrong Laboratory, RFR Division (AL/OERS), Brooks AFB, Texas. Use of these types of devices will require written approval from HQ USAF/SG on advice of Armstrong Laboratory consultants.

3.5. Investigation of Alleged Exposures to RFR. Each Air Force facility shall investigate and document all alleged incidents involving personnel exposure that may exceed the PELs in table 2.1, after including adjustments to the PEL, such as, spatial and time averaging, partial-body exposure, etc. Usually during the initial reporting phase of an incident, an experienced engineer or BEE technician can predict or estimate whether or not the individual could have exceeded the PEL, and if so by how much. This can be done locally or through contact with the consultants at AL/OERS. Following the initial estimation of exposure, the actions listed below should be taken for exposures expected to be at or above the PEL, and must be taken for exposures expected to be five times greater than the adjusted PELs in table 2.1:

- RFR measurements for documentation of the RFR exposure that may have been received.
- Medical examination and recommendations for medical followup.
- Documentation providing a description of the circumstances surrounding the exposure incident, statements from personnel involved in that incident, and recommendations to prevent similar occurrences.
- The Armstrong Laboratory, or delegated authority, will maintain a repository file for all investigations of exposure incidents in which personnel were exposed to RFR levels in excess of five times the table 2.1 adjusted PELs.

3.5.1. Assessment of Exposure. In determining whether a person has received exposure in excess of the PEL, exposure averaging times and whole-body spatial averaging are important factors in making the assessment. In other cases, (e.g. near body resonance) determination of the vertical E field component rather than the total E field is appropriate in determining whether an individual received a high exposure in terms of whole-body-averaged SARs. For low-power devices, such as hand-held, mobile, and marine transmitters, the low-power exclusion criteria of paragraph 2.9.5, can be used in assessing exposure conditions. Even though those low-power devices may have localized fields that exceed the PEL field values, the actual whole-body or spatial peak SARs will not be exceeded. The following actions must be taken whenever an overexposure is suspected or alleged to have occurred.

3.5.1.1. Immediate Actions. The individual will immediately report the incident to his or her supervisor. Medical attention should be sought within the first 72 hours following exposure. Symptoms that may be associated with the exposure field should be reported to the attending physician and recorded for medical investigation purposes. The medical examination should be accomplished, according to paragraph 3.5.4, by the Flight Surgeon's office.

3.5.1.2. The Responsible Area Supervisor. The supervisor will notify the installation Bioenvironmental Engineering Flight (BE) upon initial report of the incident and will advise all other appropriate authorities within the unit according to unit reporting procedures.

3.5.2. Bioenvironmental Engineering Flight. BE will provide initial notification of the alleged incident to the MACJCOM BEE and HQ AFMOA/SGOE. BE will conduct a preliminary investigation of the alleged incident and perform a reconstruction of the incident, to include field measurements when necessary. BE will be responsible for notification of all applicable medical authorities, such as the PH office. BE will also ensure the information listed in attachment 2 is collected and mailed or to AL/OERS, 8305 Hawks Road, Building 1182, Brooks AFB, TX, 78235-5324, telefax number DSN 240-5923. The investigation, reconstruction, and measurement of the alleged exposures will be conducted by BE according to the instructions provided in attachment 2 of this standard. If needed, BE personnel will contact AL/OERS consultants at DSN 240-3179 or 240-1182, for assistance in performing the investigation, reconstruction and/or measurements. BE will prepare a final report of the investigation and findings and provide this to the PH office.

3.5.3. Public Health. The PH office will prepare a summary of medical evaluations and findings, attach a copy of the final report of the BE investigation, and distribute the detailed final report to the recipients listed in attachment 2. The final report must be distributed within 45 work days following the completion of the investigation, and must include all of the information listed in attachment 2. The summary must conclusively state whether an overexposure did or did not occur, or state why the final determination cannot be conclusive, based on the findings from the field and medical investigations. A copy of the medical summary must be placed in the alleged exposee's medical records. If the patient is treated by a non-Air Force medical facility, then the officer or NCO in charge of PH will attempt to obtain copies of all treatment records, and include them in the summary documentation. Appropriate authorization for the release of medical information to the Air Force should be obtained from the individual prior to review of personal medical data.

3.5.4. Medical Evaluation. A post-exposure medical examination and follow-up recommendations should be performed for all reported cases within 72 hours following the alleged exposure. The initial work-up should include a standard medical history, routine medical examination, and an eye examination or visual accuity test, if the eyes were involved. Document the exposure duration and level as this information is made available, and record the patient's reported symptoms. If the reconstruction of the incident verifies exposure occurred in excess of the PEL, the treating physician may elect to perform further follow-up examinations based upon the symptoms exhibited. For example, anomolies noted during an initial eye test or exam might indicate the need for additional investigation or treatment. However, the levels required to produce any abnormalities or changes would also be expected to produce other signs and symptoms, such as reddened or burned skin around the eyes. Post-exposure exam results should be compared to the results of similar exams performed prior to the alleged exposure, whenever possible. Any anomalies that could be associated with exposure to RFR Radiation should manifest within the first 72 hours following exposure. Symptoms of shock and burns may be evident and should be treated accordingly. Any evident injury should be treated accordingly and documented. It is important not to immediately associate any reported injuries or effects with the exposure incident without first defining the amount of energy delivered to the exposure site and the duration of exposure. It is good procedure to evaluate other possible causes of exhibited symptoms, such as stress, anxiety or heat exhaustion. Cases found to be in excess of 5 times the PEL should be followed for a period of up to two weeks or until all medically substantiated symptoms have subsided, whichever occurs first. For personnel whose exposure(s) occurred at, or above, five times the PELs in table 2.1, a medical examination and recommendations for medical follow-up are mandatory. Hospitalization is not required unless the patient displays significant signs or symptoms of injury or illness that require diagnostic evaluation or treatment. With the exception of shock and burns from exposure to induced currents or contact currents, most individuals exposed to RFR in a typical Air Force operational environment will manifest little or no evidence of altered physiologic functions or symptoms of distress. A sensation of warmth has been reported at levels in excess of the PEL, and clicking or buzzing sounds may be audible in the case of pulsed emitters, but these symptoms do not last and are limited to the duration of the exposureAny reported symptoms or changes in physiologic function should be evident within the first 72 hours following the exposure. Symptoms that develop after 72 hours are probably not RFR related, but should be assessed and documented by the treating physician.

After assuring the patient's well-being, the principal concerns will be to quantify the exposure, assess exhibited symptoms and compare them to the level and duration of exposure, and to document pre-exposure and post-exposure baselines from which to measure future changes, should any occur. See attachment 5 for familiarization with the biological effects of RFR exposures and attachment 6 for recommended medical surveillance procedures.

3.5.5. Closure. Upon completion of the medical and field investigations, the patient alleging exposure must be advised of the findings and provided a copy of the written report. The patient should receive a complete explanation of the findings and given a chance to ask questions regarding his/her alleged exposure. The BE and attending AF physician should be available to answer any technical or medical questions during the final briefing of the patient.

3.6. Medical Surveillance Requirements. Routine pre-placement, baseline, periodic, and termination occupational medical examinations are not required. Post-exposure examinations will be done according to paragraph 3.5.4. Attachment 6 contains more detailed medical information from a doctor's perspective. Although routine medical occupational examinations are not required by this standard, each shop with an exposure potential should be reviewed annually by the Aerospace Medicine Council. Documentation should be provided to the council to keep them appraised of current medical exam requirements, and changes to the requirements of this standard.

3.7. RFR Safety Awareness Training Requirements. Air Force personnel who routinely work directly with equipment that emits RFR levels in excess of the PELs in table 2.1, or whose work environment contains equipment that routinely emits levels in excess of the PELs in table 2.2, shall receive initial and annual refresher training. It is the unit's responsibility to provide and document such training to all personnel. BE may be called upon to review training materials for accuracy or editorial comment. BE should review unit RFR safety training materials and attendance records during their annual industrial hygiene shop visits.

3.7.1. Initial Training. The RFR safety awareness training program must include training to make workers aware of the potential hazards of RFR, clearly identify protection procedures and control restrictions designed to limit personnel exposures, and advise workers of their responsibility to limit their own personal exposures. Initial training shall be conducted before assignment to such work areas. Initial training should include, but are not limited to the following:

- Locations where the PEL can be exceeded.
- Control measures that must be observed by workers to avoid personal exposure.
- Overview of the bioeffects that result from overexposure to RFR.
- Exposure incident reporting procedures and follow-up technical and medical investigation process.

3.7.2. Refresher Training. Refresher training should be given, at least annually, and may be incorporated into other periodic hazard communication or safety awareness training programs. The refresher training should address the following topics at minimum:

- New equipment, modifications, or other changes that affect the locations of hazardous areas.
- Control measures that must be observed by workers to avoid personal exposure.
- Incident reporting procedures.

3.7.3. The AF Form 55, **Employee Safety and Health Record**, authorized versions, or an equivalent computer-generated product that is a true, reproducible and historically accurate facsimile shall be used to record employee training.

CHARLES H. ROADMAN, II, Lt General, USAF
Surgeon General

Attachment 1

GLOSSARY OF TERMS

Terms

Antenna—A device designed for radiating (or receiving) electromagnetic energy.

Antenna Array—A system of antennas coupled together for the purpose of enhancing radiation in one or more directions and reducing radiation in other directions.

Antenna Gain or Directivity—The ratio of the radiation intensity, in a given direction, to the radiation intensity that would be obtained if the power accepted by the antenna were radiated isotropically.

Antenna Pattern—The spatial distribution of a quantity that characterizes the electromagnetic fields radiated by an antenna.

Aperture (Antenna)—A surface, near or on an antenna, on which it is convenient to make assumptions regarding field values for the purpose of computing fields at external points. NOTE: The aperture is often taken as that portion of a plane surface near the antenna, perpendicular to the direction of maximum radiation, through which the major part of the radiation passes.

Athermal Effect—(nonthermal effect) Any effect of electromagnetic energy absorption not associated with or dependent upon the production of heat or a measurable rise in temperature.

Average Power (Pavg)—The time-averaged rate of energy transfer:

$$P_{avg} = \frac{1}{t_2 - t_1} \int_{t_1}^{t_2} P(t)\,dt$$

Average Power Density—The instantaneous power density integrated over a period of time.

Averaging Time (Tavg)—The time period over which exposure is averaged for determining compliance with a PEL value.

Continuous Wave (CW)—A RF transmission in which the carrier is transmitted continuously, without any breaks. FM is an example of CW. The duty factor for a CW emitter is unity (1).

Controlled Environment—Locations where RFR exposures may exceed the levels in table 2.1, but do not exceed the levels in table 2.2. Generally, controlled environments represent areas that may be occupied by personnel who accept potential exposure as a concomitant of employment or duties, by individuals who knowingly enter areas where such levels are to be expected, and by personnel passing through such areas. Existing physical arrangements or areas, such as fences, perimeters, or weather decks of a ship may be used in establishing controlled environments.

Decibel (dB)—The logarithmic unit used to indicate relative intensities of power or voltage, equal to 10 times for power, and 20 times for voltage, the common logarithm of the ratio.

Diathermy—The medical application of RF energy to produce heat within some part of the human body for therapeutic purposes. Most diathermy equipment operates in the HF band.

Dipole—Common usage considers a dipole antenna to a metal radiating structure that supports a line-current distribution similar to that of a thin straight wire, a half-wavelength long, so energized that the current has a node only at each end.

Dummy Load—A dissipative device used at the end of a transmission line or waveguide to convert RF energy into heat, so that essentially no energy is radiated outward or reflected back to the source.

Duty Factor or Duty Cycle—The ratio of the pulse duration to the pulse period of a periodic pulse train. This is a unitless number, expressed as a decimal, fraction, or percent, which indicates the portion of time a transmitter is actually emitting RF energy. The product of pulse width (sec) and pulse repetition frequency (PRF).

Electric Field—Generally a vector field of electric field strength or of electric flux density. The term is also used to denote a region in which such vector fields have a significant magnitude. More specifically, it is a fundamental component of electromagnetic (EM) waves, which exists when there is a voltage difference between two points in space.

Electric Field Strength (E)—In terms of radio wave propagation this is expression is used to describe the magnitude of the electric field vector and is expressed in volts per meter (V/m).

Electro-Explosive Device—A pyrotechnic or explosive device designed to detonate when an electric current passes through it, commonly called a squib.

Electronic Countermeasures (ECM)—An offensive or defensive tactic which uses an electronic device to interfere with the effective use of enemy radar, radio, etc.

Electromagnetic Compatibility (EMC)—The capability of electronic equipment to be operated in the intended electromagnetic environment at design levels of efficiency.

Electromagnetic Interference (EMI)—Interference with the proper functioning of an electronic device by electromagnetic means, internal or external.

Electromagnetic Radiation—The propagation of energy in the form of EM waves through space. (Not intended to describe propagation along waveguides and other transmission lines).

Emitter—Any device which is designed to generate RF energy and couple this energy into the surrounding space.

Equivalent Plane-Wave Power Density—The normalized value of the square of the electric or the magnetic field strength at a point in the near-field of a radiating source. The value is expressed in W/m^2, (or mW/cm2) and is computed as follows:

$$S = |E|^2/377 = |H|^2 \times 377$$

Exposure, Partial Body—Partial-body exposure results when RF Fields are substantially nonuniform over the body. Fields that are nonuniform over volumes comparable to the human body occur due to highly directional sources, re-radiating sources, standing waves or when in the antenna's near-field region. For most antennas the Far-field starts at twice the diameter of the antenna divided by the wavelength.

Extremely Low Frequency (ELF)—A radio frequency below 30 Hz.

Far-Field or Fraunhofer Region—The region far enough from an antenna that the power per unit area decreases with the square of the range. In the far-field region, the field has a predominantly plane-wave character; i.e., uniform distributions of electric and magnetic fields in planes transverse to the direction of propagation. Also called the free space region and the Fraunhofer region.

Feed—The part of an antenna which couples RF energy to the antenna or reflector.

Field Strength—The magnitude of the electric field (volts and (or) meter) or magnetic field (amps and (or) meter).

Free Space—A region in the far field of an antenna which is devoid of any objects which could affect the radiation pattern. (See Far-Field Region).

Frequency—The number of cycles completed by an electromagnetic wave in one second, given in cycles and (or) second or hertz.

Frequency Modulation (FM)—A method of coding information on an RF wave in which the frequency of the wave is varied IAW the intelligence.

Height Finder—A radar system used to determine the elevation of airborne targets.

Hertz (Hz)—The unit for expressing frequency. One hertz equals one cycle per second. Commonly used multiples are kilo-hertz (kHz), megahertz (MHz), and gigahertz (GHz).

High Frequency (HF)—A frequency between 3 and 30 MHz, commonly used for moderate to long distance communication systems.

Horn Antenna—An antenna consisting of a waveguide section whose cross-sectional area increases toward the open end that is the aperture through which electromagnetic energy is radiated or received.

Human Resonance Range—The frequency region where absorption of RF energy in the body is enhanced. For sizes ranging from a baby to an adult, peak absorption varies depending on the individual's size relative to the wavelength and orientation relative to the polarization of the wave. The PELs have been established to cover the range in human sizes, shapes, and positions.

Impedance—The total opposition that a circuit or propagation path presents to an RF current or wave. The ratio of the electric field strength to the magnetic field strength.

Incident Wave—A wave traveling through a medium, in a specified direction, which impinges on a discontinuity or a medium of different propagation characteristics.

Internal Body Current—The current that is induced in a biological subject that is exposed to low-frequency RF fields.

Intrinsic Impedance (of Free Space)—The ratio of the electric field strength to the magnetic field strength of a propagating electromagnetic wave. The intrinsic impedance of a plane wave in free space is approximately 377 ohms.

Ionizing Radiation—Any electromagnetic or particulate radiation capable of producing ions directly or indirectly in its passage through matter. Examples are X-rays and gamma rays.

Isotropic Antenna—An antenna capable of radiating or receiving equally well in all directions, and equally responsive to all polarizations of electric and/or magnetic fields. NOTE: In the case of transmitting coherent electromagnetic waves, an isotropic antenna does not exist physically, but represents a convenient reference antenna for expressing directional properties of an actual antenna.

Klystron—An electron tube in which an initial velocity modulation imparted to an electron beam results in a density modulation of the beam, used as a microwave oscillator or amplifier.

Lobe—One of the three dimensional portions of the directional pattern of a directional antenna. The major or main lobe is that portion of the antenna field pattern containing the maximum radiation all other lobes, usually containing significantly less energy are side lobes.

Log-Periodic—An antenna which consists of several center-fed horizontal dipoles or vertical monopoles mounted parallel to each other in the same plane, characterized by broad bandwidth and moderate gain.

Long Range Navigation (LORAN)—An RF navigation aid which consists of master and slave ground stations.

Low Frequency—A frequency between 30 and 300 kHz.

Magnetic Field Strength (H)—The magnitude of the magnetic field vector, expressed in units of amperes per meter (A/m).

Magnetic Field Vector—A field vector that is equal to the ration of the magnetic flux density to the permeability, expressed in units of amperes per meter (A/m).

Magnetron—A type of microwave tube in which an electron beam is amplified under the combined force of a radial electric field and an axial magnetic field.

Microwaves—A term used rather loosely to signify radio waves in the frequency range from about 300 MHz upward.

Modulation—The process, or result of the process, whereby some characteristic of one wave is varied in accordance with another wave or signal. NOTE: For the purpose of this recommended practice, continuous wave (CW) operation is considered to be a special form of modulation, that is, zero modulation

Monopole—An antenna, usually in the form of a vertical pole or helical whip, which acts as one half of a dipole, the other half being formed by its electrical image in a ground plane.

Navigation Aid—An RFR emitting system which is used to assist in the navigation of an aircraft.

Near-Field Region—A region generally in close proximity to an antenna or other radiating structure in which the electric and magnetic fields do not exhibit a plane-wave relationship, and the power does not decrease with the square of distance from the source but varies considerably from point to point. The near- field region is further subdivided into the reactive near field, which is closest to the radiating structure and contains most or nearly all of the stored energy, and the radiating near field, where the radiating field predominates over the reactive field but lacks substantial plane-wave character and is complicated in structure.

Nonionizing Radiation—Any electromagnetic radiation incapable of producing ions directly or indirectly. Microwaves and RF energy are forms of nonionizing radiation.

Peak Power Density—The maximum instantaneous power density occurring during the interval when power is transmitted.

Peak Power Output—In a modulated carrier system, the output power averaged over a carrier cycle, at the maximum amplitude that can occur with any combination of signals to be transmitted.

Petroleum, Oils, Lubricants (POLs)—The common designation for flammable substances whose vapors could be ignited by RF energy.

Phased Array Radar—A radar having fixed array of many antennae, each with an electronically variable phase shifter that permits steering of the beam over wide angles without antenna motion.

Plane Wave—An electromagnetic wave characterized by mutually orthogonal electric and magnetic fields which are related by the impedance of free space (377 ohms).

Polarization (radiated wave)—That property of a radiated electromagnetic wave describing the time-varying direction and amplitude of the electric field vector; specifically, the figure traced as a function of time by the extremity of the E-field vector at a fixed location in space, as observed along the direction of propagation. NOTE: In general, the figure is elliptical and it is traced in a clockwise or counterclockwise sense. The commonly referenced circular and linear polarizations are obtained when the ellipse becomes a circle or a straight line, respectively. Clockwise sense rotation of the electric vector is designated right-hand polarization and counterclockwise sense rotation is designated left-hand polarization.

Power—A physical quantity describing the rate of delivery or transmission of energy. In this document, power will refer to radiofrequency power with units of watts (W).

Power Density (S)—Power per unit area normal to the direction of propagation, usually expressed in watts per meter squared (W/m^2) or, for hazard assessment, mW/cm^2. See also Pointing Vector.

Power Level—At any point in a transmission system, the ratio of the power at that point to some arbitrary amount of power chosen as a reference. This ratio is usually expressed as decibels referred to 1 mW (dBm) or decibels referred to 1 W (dBW).

Precision Approach Radar (PAR)—The main component of a GCA system, a radar which scans limited angles of azimuth and elevation along the final approach to a runway.

Probe-Length (Probe Antenna-Length)—The maximum physical dimension of the antenna of a near-field probe, or the dimension of the largest antenna in a multiple array.

Pulse Repetition Frequency (PRF)—In a pulse-modulated RF system using recurrent pulses, the number of pulses per unit of time.

Pulsed RF—A continuous-wave RF carrier signal that is amplitude-modulated at a known PRF with a controlled duty factor.

Pulse Width—The time width of an electromagnetic pulse, usually given in microseconds.

Radar—A system that radiates pulsed or frequency-modulated electromagnetic waves and utilizes the reflection of such waves from distant objects to determine their existence or position. The name is derived from initial letters in the expression Radio Detection and Ranging.

Radar Approach Control (RAPCON)—The radar facility responsible for directing and controlling the aircraft in the general vicinity of an airport.

Radiation Intensity—In a given direction, the power radiated from an antenna per unit solid angle in that direction. The units are watts per steradian (W/sr).

Radiofrequency Radiation Hazard Meter (Monitor)—An instrument that is capable of measuring spatially localized electric and/or magnetic field strengths under near and far-field conditions. The instrument consists of a sensor with an antenna suitable for the wavelength under study, plus a means for transmitting information from the sensor to a suitable field strength indicator.

Reflected Wave—A wave in a medium produced by reflections from objects or discontinuities in the medium or from a boundary of a different medium.

Re-radiated Field—An electromagnetic field resulting from currents induced in a secondary, predominantly conducting object by electromagnetic waves incident on that object from one or more primary radiating structures or antennas. Re-radiated fields are sometimes called "reflected" or, more correctly, "scattered fields". The scattering object is sometimes called a "reradiator" or "secondary radiator". See: Reradiator.

Reradiator, Passive or Parasitic—Electrically conducting structures that, when illuminated by a primary RF source or ambient electromagnetic fields, act as a secondary radiating source because of currents induced in the structure. In some cases, reradiators can produce localized EM fields significantly more intense than the fields that are associated with the primary source.

Response Time—The time required for a field-measuring instrument to reach some specified percentage of the final value after being placed in the field to be measured. In this document, 90 percent of the final value is assumed.

RF "Hot Spot—A highly localized area of relatively intense RF Field that manifests itself as:

- Intense electric or magnetic fields immediately adjacent to conductive objects immersed in lower intensity ambient fields.
- Localized areas where there exist a concentration of RF fields caused by reflections or narrow beams produced by high-gain radiating antennas or other highly directional sources.
- For both descriptions, the fields are characterized by very rapid changes in field strength. RF hot spots are normally associated with very nonuniform exposure of the body (partial-body exposure). The term RF hot spots should not be confused with an actual thermal hot spot in an absorbing body.

Rhombic—A very large, horizontal HF antenna consisting of four corner poles which support a diamond-shaped wire structure, fed at one apex by a transmission line and terminated with an impedance network at the opposite apex.

Root-Mean-Square (rms)—The effective value, or the heating value, of a periodic RF wave. The rms value for E or H fields is obtained by taking the square root of the mean of the squared values for E or H over an area equivalent to the vertical cross-section of the human body (projected area).

Scattering—The process that causes waves incident on discontinuities or boundaries of media to be changed in direction, frequency, phase, or polarization.

Search Radar—A radar system which constantly scans a region of space and displays aircraft as soon as they enter the region; used for early warning, ground-controlled approach, and air traffic control.

Slot Antenna—A metal plate with a long narrow aperture cut into it, which is normally one half wavelength long. The aperture is energized by means of a cavity placed behind it, and a waveguide or a transmission line connected across it.

Specific Absorption Rate (SAR)—The time rate at which RF energy is imparted to an element of biological body mass. Average SAR in a body is the time rate of the total energy absorbed divided by the total mass of the body. SAR is expressed in units of watts per kilogram (W/kg). Specific absorption (SA) refers to the amount of energy absorbed over an exposure time period and is expressed in units of joules per kilogram (J/kg). The time derivative (rate) of the incremental energy (dW) absorbed by an incremental mass (dm) contained in a volume element (dV) of a given density (ρ).

$$SAR = d / dt(dW / dm = d / dt(dW / \rho dV)$$

SAR is expressed in units of watts per kilogram (W/kg).

Standing Wave—A spatially periodic or repeating field pattern of amplitude maxima and minima that is generated by two equal-wavelength propagating waves traveling in different directions. For any component of the field, the ratio of the amplitude at one point to that at any other point does not vary with time.

Standing Wave Ratio—The ratio of maximum field strength to minimum field strength along the direction of propagation of two waves traveling in opposite directions on a transmission line.

Tactical Air Navigation (TACAN)—A radio navigation aid which provides accurate slant range and bearing information to aircraft. A VORTAC is a combination of TACAN and VOR.

Time Averaged Power Density—The average power density integrated over the longest source period. This period can be as a result of rotational or directional characteristics of the source. Units of this quantity are W/m^2 or mW/cm^2.

Transmission Line—A system of conductors, such as wires, waveguides, or coaxial cables, which conducts RF energy between points in an RF system.

Traveling Wave Tube (TWT)—An electron tube in which a stream of electrons interacts with a guided electromagnetic wave resulting in a transfer of energy from the stream to the wave, used as a microwave amplifier.

Uncontrolled Environments—Locations where RF exposures do not exceed the PELs in table 2.2. Such locations generally represent living quarters, workplaces, or public access areas where personnel would not expect to encounter higher levels of RF energy.

Waveguide—An enclosed system capable of guiding electromagnetic waves from one place to another. Usually it consists of a hollow metallic tube or a solid dielectric material.

Wavelength—The distance between two points having the same phase in two consecutive cycles of a periodic wave.

Yagi—A type of directional antenna which has one dipole connected to the transmission line and a number of equally spaced unconnected dipoles mounted parallel to the first in the same plane which serves as directors and reflectors.

Attachment 2

ALLEGED RFR EXPOSURE INCIDENT INVESTIGATIONS AND REPORTS

A2.1. Requirements.

Requirements for investigating and reporting alleged exposure incidents are specified in the main text of this standard, paragraph 3.5. This attachment was developed to assist the base level investigator(s) with the investigation and reporting process. Consultative services are available through the Armstrong Laboratory, RFR Division, Sources and Measurements Branch, (AL/OERS) for assistance with the reconstruction and measurement of alleged exposure incidents.

A2.2. Investigate and Reconstruct.

Taking care to protect yourself and your instrument, reconstruct the incident. Measurements should be made using the system parameters that were used when the incident occurred, but the beam must be fixed in a stationary position. A rotational duty factor can be calculated and multiplied times the stationary power density measurement to obtain the individual's actual exposure level from the moving beam. See the formula for rotational duty factors in attachment 3, paragraph C4, Scanning Correction. It is highly unlikely that an overexposure could occur from a rotating beam, yet measurement and reconstruction of the incident will go far to allay the fears and concerns of the alleged exposee, and to circumvent potential litigation. In the event the expected power density at the point of exposure is greater than the scale of the instrument or the PEL, you should make multiple measurements starting from before the expected PEL distance and move up in increments until the PEL is reached. Measurements above the PEL, but below the instrument limit, can also be made if necessary provided 6 minute averaging criteria are considered. These incremental measurements can be plotted as data points on semi-log paper and used to estimate the actual exposure value. An example of how to reconstruct an RFR exposure incident is provided below:

A2.3. Example Reconstruction.

This example will briefly explore calculations and measurements used in a possible RFR overexposure investigation. The example will assume an individual was exposed to an AN/APQ-128, terrain following radar, located in the nose of an F-111 aircraft. The individual was located approximately 5 inches from center of the antenna on the main beam axis for approximately 45 seconds. The following parameters apply to the AN/APQ-128:

Frequency = 16.7 - 17.0 GHz	Peak Power = 30 kilowatts
Pulse Repetition Frequency = 4045 pps	Pulse Width = 0.2 usec
Power Average = 24 watts	Antenna Gain = 25.5 dBi
Absolute Antenna Gain = 355	Vertical Beam Width = 8.0 degree
Horizontal Beam Width = 8.20	Reflector Length = 7.3 in - Reflector Width = 6.4 in

A2.3.1. From the basic background information given above we should be able to estimate the maximum power density incident on the individual. The first step in this process is to determine the near- and far-field boundaries. Since the AN/APQ-128 emits at 16.7 - 17.0 GHz, we will calculate the system emission wavelength, then calculate the limits of the near-field zone, as follows:

System Wavelength:

$\lambda = c / f$,

$= (3 \times 10^8 \text{ m/s}) / (16.85 \times 10^9 \text{ 1/s})$

= 0.0178 meters, where the frequency, *f*, is the median value between 16.7 and 17.0 GHz.

Calculate Near Field Boundary:

$$\text{Near-Field} < L^2/4\lambda,$$

$$< 0.185^2/4 \times 0.0178$$

$$< 0.48 \text{ meters (19 inches)},$$

where, our value for L in the near-field equation is the longest dimension of the antenna, the reflector width of 7.3 inches; note the conversion from inches to meters: (7.3 in x 2.54 cm/in) (meter/100 cm) = 0.185 meters

A2.3.1.1. From the calculations above, it is apparent that the individual was located well within the near-field of the emitter and, therefore, a near-field estimation is most appropriate.

A2.3.2. Since the antenna area is not given in our list of parameters, we must first calculate the area of the reflector. The reflector is elliptical in shape. However, for our purposes, we will assume the reflector is rectangular for simplicity. Antenna area is calculated as follows:

$$\text{Area} = \text{Reflector Length} \times \text{Reflector Width},$$

$$= 7.3 \text{ inches} \times 6.4 \text{ inches},$$

$$= 46.7 \text{ inches}^2,$$

$$= 46.7 \text{ in2} \times \frac{[2.54 \text{ cm}]^2}{\text{in}^2} = 301 \text{ cm}^2$$

Now we are ready to calculate the maximum main-beam power density (S), as follows:

$$S = (4 \times P_{av}/A)$$

$$= (4 \times 24000 \text{ mW})/301 \text{ cm}^2$$

$$= 318 \text{ mW/cm}^2$$

A2.3.3. A power density of 318 mW/cm^2 is an extremely large value when compared to the standard for this frequency range, 10 mW/cm^2. A calculated value of this magnitude is very common for an emitter of this size and type, and for an exposure this close to the antenna. We have theoretically predicted the maximum peak power density in the main beam. However, for a narrow beam from a small emitter like the AN/APQ-128, the spatial region where the field intensity is this large is likely to be very small; it is unlikely that the measurement instrument will be able to detect this field because the effective area of the probe elements are greater than the spatial region of interest. This concept is illustrated very well by measured values of 180 mW/cm^2 at 5 inches from the AN/APQ-180 antenna, as documented by AL/OERS.

A2.3.4. Finally, to estimate the exposure to the individual we will perform a simple time average of the exposure over a 6-minute period as shown below:

$$\text{Power Density Average} = \frac{(180\ \text{mW/cm}^2 \times 45\ \text{sec}) + (0\ \text{mW/cm}^2 \times 315\ \text{sec})}{360\ \text{seconds}} = 22.5\ \text{mW/cm}^2$$

A2.3.4.1. The individual was exposed to levels above the PEL. If at any questions, doubt, or concerns about the findings arise at any time during the investigation, contact AL/OERS for guidance.

A2.4. When determining the total exposure, the duration of the exposure must be known. Time estimates of the exposee and witnesses may vary and can be exaggerated. Using a stop watch, ask the alleged exposee to repeat his/her actions and log the time accordingly.

A2.5. Photographs are a very important part of the investigation. Ensure that the transmitter is off, position everyone as they were during the incident, and photograph the incident from various angles. The base photo lab may perform the photography, under the supervision of the on-site investigator.

A2.6. A complete, detailed report of the investigation must be prepared, including photographs, measured data, who, what, when, and where the incident occurred, and medical findings (if any). A physical examination should be performed for anyone exposed in excess of the PEL, but MUST be performed if the individual was exposed to levels at or above 5 times the PEL. See Attachment 6 for recommended medical surveillance. The following is a list of minimal information that absolutely must be included in your final report:

Date of Incident

Last Name, First Name, Middle Initial of Exposee

SSAN

Rank

Employer

Location of Incident (Base)

Emitter Nomenclature

Emitter Frequency (MHz)

Permissible Exposure Limit (mW/cm^2)

Maximum Exposure Level Measured (mW/cm^2)

Exposure Duration (minutes)

Time Weighted Average Exposure (mW/cm^2 x Exposure Time/6-minutes)

Target Organ (head, whole body, extremities, eyes, gonads, etc.)

Was the Person Overexposed (draw a final conclusion from the investigation)

Initial Medical Action Taken (routine exam, eye exam, etc.)

Symptomatic/Asymptomatic? (if symptomatic, describe symptoms)

Follow-up Recommended? (does attending physician recommend further tests, etc.)

Investigator's name, rank, phone number.

Add any additional comments or information that seems pertinent.

A2.7. Communication is essential before, during, and after reconstruction of an incident to ensure that all personnel and agencies involved receive the correct information. The goal of the investigation is to a) determine if the individual was, in fact, exposed, b) determine the severity of the exposure to ensure that proper medical assessments are performed, c) identify operational deficiencies to avoid recurrence. If the investigation concludes that the individual was not overexposed, then the investigator should be able to alleviate any anxiety and prevent future incidents through informative review of the findings and future education.

A2.8. BE will notify AL/OERS, regardless of whether consultative services are required, using the format specified in figure 6. The investigator will prepare the detailed final report of investigation within 45 days following completion and provide a copy to PH. PH will prepare a summary of the BE findings and distribute the detailed final report to the addressees listed below:

AL/OERS

8305 Hawks Road, Bldg 1182

Brooks AFB, TX 78234-5324

Bioenvironmental Engineers of all Major Commands involved

Public Health Officers of all Major Commands Involved

Safety Office of all Major Commands involved

Commander of the operational unit (squadron, etc.) involved (***NOTE:*** the unit commander will ensure shop supervisor, etc. receives a copy of the final report).

Safety Office of the installation where the incident occurred

Attachment 3

THEORETICAL EVALUATION PROCEDURES

A3.1. AF Form 2759, **Radiofrequency Radiation Emitter Survey Data**. Data necessary for performing a theoretical hazard evaluation of an RFR emitter is shown on the AF Form 2759. The following guidelines can be used to obtain the required data.

A3.2. Determining Power Ratings of an Emitter.

The power rating of a transmitter must be known to evaluate an RFR system. All emitters transmit with either a continuous wave (CW) or a pulsed RFR signal. A CW system is one which is designed to produce its output in continuously successive oscillations (continuous waves). Rated output is normally average power. For pulsed systems, transmitter power is usually expressed as peak power. A system designed to produce its energy in short pulses or bursts, repeated at regular intervals, is therefore known as a pulsed system. In a pulsed system, average power is the peak power multiplied by the duty cycle (DC). Mathematically, the duty cycle is the product of the pulse width (PW) multiplied by the pulse repetition frequency (PRF). Alternately, it can be thought of as the ratio of the pulse width to the pulse period (i.e., 1 / PRF) of a periodic pulse train. The amount of time that each output pulse or burst of RFR energy is on is the PW, while the PRF is the number of output pulses per unit time, usually expressed in hertz (sec -1).

DC = PW (sec) x PRF (sec-1), a dimensionless quantity less than 1 [Eq. A3-1]

Paverage = Ppeak x DC [Eq. A3-2]

Transmitter power can be specified in many units. Typically it is given in terms of watts (W), of kilowatts (kW). Another common unit is that of the dBm, which is a unit of power referenced to 1 milliwatt (mW). 0 dBm is equivalent to 1 mW. Other power levels are related to 1 mW by:

P(dBm) = 10 log10 (P1)/(1 mW) [Eq. A3-3]

P(mW) = $\log^{-1}$[P(dBm)/10] [Eq. A3-4]

Thus an output power of 1 kW (1000 W), would be equivalent to 60 dBm.

A3.3. Transmission Lines and Associated Hazards.

There are two basic types of RFR transmission lines: one conductor and two conductor. A one conductor transmission guide propagates RFR through a hollow tube called a waveguide at microwave frequencies. There are numerous types of two conductor transmission lines, the most common being single coaxial line and parallel wires. These type of conductor lines are most commonly encountered at frequencies less than 1 GHz. It is important to be cognizant of the hazards associated with transmission lines. In particular, leaky or broken waveguides can propagate RFR like an antenna. The size of a waveguide break is the most important factor in determining its ability to behave like an antenna. For example, if the largest dimension of the break is smaller than one-half the wavelength, the break will not effectively emit RFR. On the other hand, if the break's greatest dimension is greater than one-half the system wavelength, the break could effectively emit RFR.

A3.4. Understanding Antenna Gain and Regions.

A3.4.1. As was mentioned earlier, an antenna is a basic component of any RFR system. Regardless of the systems application all antennas have basic properties that can be well defined. Of these, gain, size, accessibility, and radiation pattern are of principle interest in the evaluation of RFR hazards.

A3.4.2. Antenna gain is the ratio of the power gain of an antenna referred to as a standard antenna, which is usually an isotropic emitter of RFR energy. An isotropic antenna is a hypothetical antenna radiating or receiving equally in all (4p) directions. Figure A5.4 illustrates an isotropic emitter.

A3.4.3. In the case of electromagnetic waves, isotropic antennas do not exist physically but represent convenient reference antennas for expressing directional properties of actual antennas. An isotropic antenna would have a gain of one. Gain, therefore, can be thought of as a measure of directionality of an RFR emitter. It may be expressed as a pure number, or more commonly, in terms of decibels. It is therefore important to briefly review the decibel system. The decibel (dB), is a unitless quantity used to express a numerical ratio. For power considerations the decibel is equal to 10 times the logarithm of a power ratio expressed by the following:

$$dB = 10 \log10 (P1)/(P2) \qquad \text{[Eq. A3-5]}$$

A3.4.4. where P_1 and P_2 are two amounts of power. The ratio of P_1/P_2 is also known as the absolute gain, Gabs of the antenna. Power ratios in decibels can be added or subtracted like ordinary numbers (see the table below). The decibel scale is a convenient device for describing relative power magnitudes which may differ by orders of magnitude. P_2 may also be a particular reference level against which other power levels are compared. For example, dBw represents dB with respect to a reference level of 1 watt, while dBm represents dB with respect to a reference level of 1 milliwatt. It is important to note that the dB scale represents a dimensionless ratio of two physical quantities, while the dBm scale represents an actual power level. The dB system may also be used to relate changes in voltage levels (or electric field strengths). Since the dB system is based on power ratios and since power depends on the square of the voltage, if we compare voltage levels we have:

$$dB = 20 \log_{10}(V_1)/(V_2) \qquad \text{[Eq. A3-6]}$$

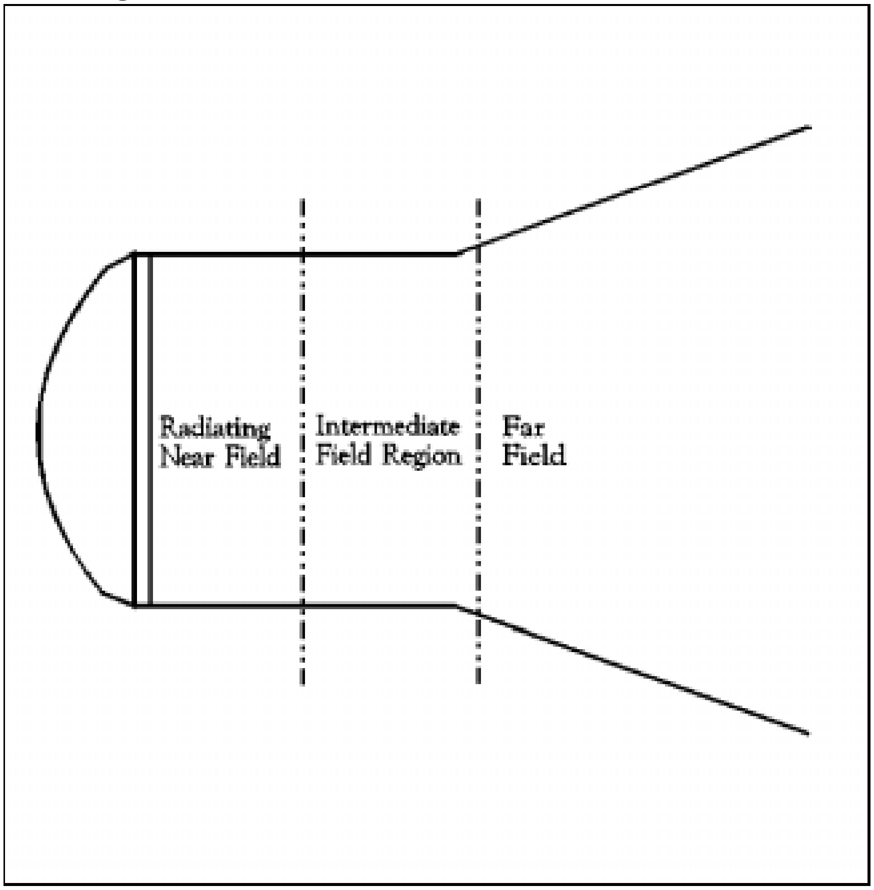
Operation	**Result**	**Physical Meaning**	**Allowed?**
dB+dB	dB	product of 2 numbers	yes
dB-dB	dB	comparing 2 numbers	yes
dBm+dBm	XX	product of 2 powers	no
dBm-dBm	dB	comparing 2 powers	yes

dBm+dB	dBm	power amplification	yes
dBm-dB	dBm	power attenuation	yes

The following summarizes how various combinations of dB units can algebraically be combined:

A3.4.5. Practically, the range of antenna gains is from 2 dB for a dipole, to 70 dB for a very narrow aperture antenna. The electromagnetic field radiated from an antenna varies greatly in configuration, depending on the distance from the emitter. Figure A3.1 details a two-dimensional representation of the regions around an aperture antenna.

Figure A3.1. Antenna Regions.



A3.4.6. The near field of an antenna can be divided into two distinct regions. The reactive near field is that region of the field immediately surrounding the antenna where the reactive energy of the electromagnetic field is recovered and re-emitted during successive oscillations. True reactive near field conditions exist only to a distance of less than one-half wavelength of the emitted radiation from the radiator. Power density has no physical meaning in this region. Practically speaking, this region is important only at frequencies below 300 MHz, where independent measurement of E and H fields must be made to completely quantify the RFR field (ANSI, 1981). In the radiating near field region, the power density is not inversely proportional to the distance from the source. It is sometimes called the Fresnel region. In this region the power density increases irregularly with range to a maximum level then decreases at a near linear rate to the onset of the far field region. It is convenient and adequate from a personnel hazard viewpoint to consider the power density in the radiating near field to be constant with range, and equal to four times the average power density calculated at the antenna aperture itself. Such a power density profile has proven accurate when compared to measured results. The intermediate field region is that portion of the Fresnel region of an antenna where the power density is decreasing at a near 1/r rate with range. It is sometimes ignored in hazard calculations. In the far field region (sometimes called the Fraunhofer region), power density is inversely proportional to the square of the distance from the source . In this region the electric and magnetic fields are perpendicular to each other, thus making it possible to make meaningful power density measurements. The impedance of free space in this region is 377 ohms, therefore measurement of either the E or H field is sufficient to completely characterize the RFR field.

A3.4.7. The methodology presented in the remainder of this section will enable the BEE or others concerned with RFR safety to make a very conservative estimate of the hazard distances involved which will then be useful as a starting point in making actual field measurements. It is based on basic antenna theory (Mumford, 1961; Hankins, 1986). The factor of conservatism will vary from as little as one, to as great as five, depending on how far from the antenna the far field actually begins. There are some small aperture antennae in the microwave frequency bands that have short near fields where these equations will yield very accurate predictions. The important point to remember is that any method other than actual measurements is only an estimate and/or prediction, and all are markedly influenced by a variety of factors, most of which are poorly understood. Actual measurements are always preferable, but estimates are useful as tentative numbers and for a starting place for any survey.

A3.5. Developing a Complete Theoretical Analysis.

As was mentioned above, when an antenna is radiating into space, it is generally agreed that there are four distinct zones or regions wherein dissimilar behavior of the antenna's electromagnetic field is experienced. These zones include the reactive near field region, the radiating near field region, the intermediate and the far field region. The reactive near field region predominates over a very short range, usually less than 0.5 wavelengths (actually l/2p) from the active antenna element. Because of the short wavelengths involved, this region is not usually significant in the microwave portion of the spectrum. The reactive near field can become important when dealing with resonant type antennas at frequencies below 300 MHz at power levels greater than 35 W. It is in the reactive near field region that separate measurements of E and H fields should be accomplished in order to produce a meaningful hazard survey. In the radiating near field, the energy is collimated in a beam having approximately the same size and shape as the far field beam. The radiating near field oscillates sinusiodally in amplitude with increasing range. The maxima are four times greater than the average power density So measured at the antenna aperture for an ideal antenna with 100% illumination. This average power density is given by:

$$S_o = P_{ave} / A \qquad \text{[Eq. A3-7]}$$

Where P_{ave} = The average transmitter power that is available for radiation after transmission line losses are subtracted. In pulsed systems P_{ave} = Peak Power x Duty Cycle. A is the actual physical or effective area of the antenna aperture.

As was mentioned earlier, in the radiating near field it is convenient and adequate from a personnel hazard viewpoint to consider the power density in the radiating near field to be constant with range. The maximum radiating near field power density S_{nf} is:

$$S_{nf} = h\ 4\ P_{ave} / A \qquad \text{[Eq. A3-8]}$$

where h is the antenna aperture efficiency, typically on the order of 0.5 to 0.75. In the intermediate field the power density is decreasing by a 1/r relationship with range, and can be represented as:

$$S_{if} = S_{nf} (R_{nf} / R) \qquad \text{[Eq. A3-9]}$$

where Rnf is the extent of the near field and R is some range in the intermediate field. For a circular antenna, R_{nf} is given by:

$$R_{nf} = D^2 / 4\ l \qquad \text{[Eq. A3-10]}$$

where D is the antenna diameter and l is the wavelength of the radiation.

In the far field an antenna has the characteristic that the power density Sff decreases as the inverse square of the range. Equation 3.11 is a precise statement of the value of Sff as a function of transmitter power, antenna gain, and range. This equation, the Friss free-space transmission formula, predicts the worst-case envelope of radiated power density from any antenna system. It is technically only accurate for plane-wave, far field conditions, though it can be used successfully as a worst-case predictor to zero range, where S would approach an infinite value. The formula is as follows:

$$Sff = P_{ave}\ G / 4\ p\ R^2 \qquad \text{[Eq. A3-11]}$$

where Sff is the power density on axis; Pave is the average power available for radiation; G is the absolute gain expressed as a power ratio; and $R > R_{ff}$, the distance which marks the beginning of far field conditions. For circular antennas Rff is given by:

$$R_{ff} = 0.6\ D^2 / l \qquad \text{[Eq. A3-12]}$$

At the above distance, the power density falls to below 10 dB of its maximum value in the radiating near field as given by equation 3.8, and true far field conditions are reached.

If the gain of the antenna is not known, it can be closely approximated by the following:

$$G = 4^{1}\ A\ h / l^2 \qquad \text{[Eq. A3-13]}$$

where l is the wavelength of the radiated energy, h is the antenna efficiency and A is the actual antenna aperture area. Combining equations 3.8 and 3.13 yields:

$$S_{nf} = 16\ p\ P_{ave}\ h^2 / G\ l^2 \qquad \text{[Eq. A3-14]}$$

Equation 3.11 can be solved for range as follows:

$$R = \tilde{A} (P_{ave} G / 4 p W) \qquad \text{[Eq. A3-15]}$$

Once a power density is calculated using equation 3.11, the power density W_2 at any other distance R_2 in the far field is given by:

$$W_1 / W_2 = (R_2)^2 / (R_1)^2 \qquad \text{[Eq. A3-16]}$$

The above treatment was derived specifically for antennas with circular apertures. However, the above treatment can be extended to non-circular aperture antennas by representing them by a circular aperture of the same physical size and gain. In this case we can generalize our antenna equations as follows:

$$R_{nf} = G l / 4 p^2 h \qquad \text{[Eq. A3-17]}$$

$$R_{ff} = 0.6 G l / p^2 h \qquad \text{[Eq. A3-18]}$$

The equations for Snf, Sif, and Sff and G are as before.

The effects on the above calculations if a system is rotating or "nodding" can now be shown. The power density produced at any point by an antenna which is rotating is given by:

$$S = S_s \text{ x } f \qquad \text{[Eq. A3-19]}$$

where Ss is the stationary power density and f is the so-called "rotational reduction factor". In the near field, the beam is considered to have a dimension in the plane of rotation equal to the length of the antenna axis, L in that plane. The near field rotational correction factor, fnf, at R is given by:

$$f_{nf} = L / R Q_s \qquad \text{[Eq. A3-20]}$$

where L equals the antenna dimension in the plane of rotation, R is the distance from a point in the near field to the antenna, and Qs is the scan angle in radians. The power density calculated in the near and intermediate field using the above reduction factor is an overestimate, but is consistent with the conservative approach used in hazard calculations. The reduction factor fff, which Sff is multiplied by to determine the time-averaged power density found in the far field of a scanning antenna is given by:

$$f_{ff} = Q¤ / Q_s \qquad \text{[Eq. A3-21]}$$

where Q¤ is the half-power beam width of the antenna and Q_s is the scanning angle of the emitter. It is important to realize that f is independent of the scanning rate in revolutions per minute.

A3.5.1. It should be noted that experience has shown that only about 15% of the RFR emitters account for the bulk of the measurement problems encountered in managing a safety program. In some cases the calculations detailed in this section may not be required. There are a number of classes of emitters that may easily and promptly be removed from these calculations, however. For example, hand-held transreceivers, commonly known as "bricks", which operate from 136 to 174 MHz and at the 510 MHz regions of the spectrum are considered to be nonhazardous to personnel if they emit less than 7 watts. (Note that there will be some changes in the 7 watt exclusion in the new ANSI/IEEE RFR Standard when it comes into force These were not definitively available at press time). As another example, many high-powered emitters have main beams which are normally inaccessible to personnel. Hazard calculations performed on these systems would be for academic interest only. A large class of emitters have characteristics which have been validated after a large number of surveys performed on them. Finally, it is important to note that there is a wealth of survey information on many "off-the-shelf" systems performed by many federal and state agencies. This data, coupled with interaction with the manufacturer of the system in question, can prove invaluable.

A3.5.2. Finally, although the above treatment will provide reasonably accurate information for safety professionals when determining the hazards around a single emitter, calculations in a multi-emitter environment are much more difficult without the use of sophisticated computer programs.

Bibliography

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[2] Mumford,W.W,"Some Technical Aspects of Microwave Radiation Hazards", IREP proceedings, no. 49, pp. 427-447, Feb. 1961.

[3] USAF, Electromagnetic Radiation Hazards Technical Manual, “TO”, 31Z-10-4, Aug. 1966, US Dept. of the Air Force, 1966.

Attachment 4

ON-SITE INSPECTIONS AND MEASUREMENT SURVEYS

A4.1. Purpose.

The purpose of this attachment is to provide the user with instructions and guidelines for performing RF power density measurements in typical Air Force environments. This attachment is not all inclusive. More extensive guidance is available in the IEEE Standard C95.3-1991, IEEE Recommended Practice for the Measurement of Potentially Hazardous Electromagnetic Fields - RF Microwave. The latter includes, but is not limited to, recommended practice for far field, near fields, induced current, and contact current measurements.

A4.2. Site Inspection Surveys.

The site inspection visit will determine if the beam is accessible to personnel and if power density measurements will be required. The visit will simply verify the conclusions drawn during the initial recognition and theoretical evaluation processes. For systems where the beam is clearly inaccessible to personnel during normal operations, no survey measurements will be required. All operating procedures and work practices must be thoroughly evaluated to ensure that there are no conditions under which the beam is lowered or fixed such that it becomes accessible to personnel. Documentation of the findings should be accomplished in the appropriate case file. If circumstances warrant, measure the power density levels in all accessible areas. Measured data from surveys conducted elsewhere may be substituted for on-site measurements, if the emitter components (transmitter & antenna) are the same, the systems operate under the same conditions, and they use the same operational parameters. Documentation in the facility case file must clearly state the source of the measured data and must include an evaluation of the measured data relative to local environment conditions. Any areas that remain questionable under local conditions should then be measured and documented to ensure that no accessible personnel hazards exist in the operating environment.

A4.3. Safety Precautions.

Personnel should take appropriate safety precautions while conducting surveys, and the degree of care exercised should increase in proportion to the power levels associated with the systems being surveyed. The nature of the precautions will also differ for leakage surveys compared with measurements of deliberate radiating systems (antennas).

A4.3.1. Ancillary (Indirect) Hazards. Surveyors should be aware of ancillary hazards associated with RFR emitter operation prior to conducting measurement surveys. The following paragraphs are provided to increase the surveyor's awareness of ancillary hazards. The information provided below is not intended to be all inclusive. If ancillary hazard issues or questions arise outside the scope of this information, the surveyor should contact one of the agencies listed herein as the primary source of information for that topic.

A4.3.1.1. High Voltage. Electrical and electronic equipment can present potential and lethal shock hazards. Ordinary precautions such as not defeating interlock protection systems, exercising care around necessarily exposed high voltage leads and terminals, and avoiding working alone near high-voltage systems, should be remembered. It should be noted, that in many high-power systems a prime RF-leakage source may be the high-voltage electrodes of the transmitting tubes.

Additional caution is advised when performing measurements in the vicinity of conductive structures, such as tall cranes or long vertically suspended cables, that are located near high-power, low-frequency RF sources. In such circumstances, large open-circuited voltages can exist on the structures that are exposed to ambient RF fields; these voltages may reach levels of several kilovolts and have the potential for arcing to a grounding body, leading to strong startle responses, and in some cases, severe RF burns. Appropriate precautions should be exercised before contacting improperly grounded objects in strong RF fields.

A4.3.1.2. X-Ray Hazards. In high-power systems utilizing high-voltage transmitting or other high-power tubes (greater than about 20 kV), there is generally the potential for X-Ray emission. These systems typically use klystron, magnetron or thyratron tubes. Cabinets containing these high voltage tubes are typically interlocked. In some instances, personnel may bypass these interlocks during some maintenance operations. Ionizing radiation measurements may be required to determine the extent of any X-Ray exposure received as a result of these maintenance operations. When making these measurements, the surveyor should ensure they are using an appropriate RFR shielded instrument. Measurements should be taken in all operating configurations and locations which could potentially expose personnel to x-radiation. Extreme caution such be exercised when attempting to measure these ionizing radiation levels due to the potential for high voltage arcing. For more information on this topic, contact AL/OEBZ, DSN 240-3486.

A4.3.1.3. DC Magnetic Fields. Some systems may include sources of strong-static and low-frequency magnetic fields (e.g. 60 cycles). Also, strong magnetic fields, (such as with MRIs, etc.) have been known to cause tools to fly out of the surveyor's pockets, etc., causing personnel injury.

A4.3.1.4. Indirect RFR Hazards. It is important to remember that the presence of RF fields can produce hazards, or at least undesirable effects, besides those arising from exposure of body tissue. Serious hazards are associated with the potential exposure of electroexplosive devices (EEDs), combustible gas, or flammable materials to RF fields.

A4.3.1.4.1. Electromagnetic Interference. The surveyor should realize that potential interference to electronic devices or systems often occurs at levels far below those that can cause bodily harm. This interference may be only an annoyance, such as interference with TV or consumer electronic devices in homes, or it may be more serious, such as the possible reprogramming or "upsets" of microprocessor -controlled medical devices, e.g., pacemakers. Errors in digital computers controlling industrial processes is another possibility. Such interference is undesirable, and care should be exercised when performing measurement surveys that may require abnormal operational settings. On Air Force installations, many potential interference problems have already been identified during the initial installation of the system. The 738 Engineering Installation Squadron, Electromagnetic Environmental Effects Section, (738 EIS/EEEX, 801 Vandenberg Avenue, Suite 201, Keesler AFB MS 39534-2634, DSN 597-3920), is the Air Force focal point for electromagnetic compatibility surveys and studies and provides on-site interference investigations. This agency may be able to provide site-specific information on the system in question. Reports and information provided by EIS may be used to assess the impact of potential interference problems before beginning a survey. It is also understood that surveys are to be made with responsible adherence to the rules of the Federal Communications Commission and other bodies that regulate against RF interference. Information on the Air Force Spectrum Interference Reduction (AFSIR) program can be found in AFI 10-707. The Joint Spectrum Center (JSC), 120 Worthington Basin, Annapolis, MD 210402-5064, DSN 281-2681, is responsible for interservice interference problems only.

A4.3.1.4.2. EEDs (also called squibs) are associated with many aircraft weapon systems. These are small explosive devices that are detonated by an electric current, often in order to detonate larger explosive devices. Many different hazard levels are defined in AFM 127-100, depending on the configuration of the EEDs in question. If an EED hazard is suspected to be present, the surveyor should contact the Weapons Safety Office on base. If the issue cannot be resolved locally, contact ASC/ENACE, Wright-Patterson AFB, OH 45433-7630, DSN 785-2907. The 738 EIS/EEEX can perform measurements for identifying hazards associated with EEDs. Safe exposure distances for EEDs relative to various transmitters, as prescribed in ANSI/IME 20-1978 [3], (or current revision thereof), should also be followed.

A4.3.1.4.3. Combustible Gas and Flammable Materials. Flammable vapors from petroleum, oil and lubricant (POL) products commonly used on Air Force installations could be ignited by an arc produced from RFR energy, under the right conditions. The safety standard for POL is 5 Watts/cm^2, based on peak power. Any location where flammable vapors could be released, such as during the transfer of fuel from one tank to another, is suspect. TO 31Z-10-4 provides more information on this topic. The primary source of information on POL hazards is the 738 EIS/EEEX, 801 Vandenburg Avenue, Suite 201, Keesler AFB, MI 39534-2634, DSN 597-3920.

A4.3.2. Burns (Associated with High-Power Fields). One should take care to prevent RF burns resulting from handling conducting objects exposed to these fields or RF cables with exposed connectors. In addition, one should follow ordinary precautions in the operation of RF heating systems and plastic sealers during surveys, e.g., avoid handling test loads, sealing bars, and superheated liquids.

A4.3.3. Abnormal Modes of Operation. The surveyor should be aware that electronic systems have the potential for abnormal modes of operation in which spurious frequencies and unintended leakage are generated at significant power levels. The surveyor should not attempt to operate the system without qualified personnel present to assess the normality of operation.

A4.3.4. Precautions During the Field Survey Process (Direct Hazards). Serious precautions are clearly required when surveying a radiation system, such as a high-power radar. Such precautions include the following:

A4.3.4.1. Based on known parameters of the system, the survey process should be planned so as to limit exposure of all personnel to levels below the PEL specified in table 2.1. This limitation relates not only to power density, but also exposure duration. If survey personnel are exposed to field strengths in excess of those specified in the PEL for continuous exposure, they should be accompanied by other personnel who can ensure that the exposure duration does not exceed the time recommended in the PEL for exposure to higher level fields. In such situations, it may be desirable to conduct the survey with radiation-emitting equipment operating at a reduced power level and use power scaling to compute the corresponding field levels that would exist during full-power operation.

A4.3.4.2. The operation of movable or scanning antennas should be done with full allowance for safety precautions. These precautions range from avoiding injury from bodily collision with rotating or moving structures, to avoiding start-up operation RF generators with antennas pointed in the direction of personnel. Before a survey begins, antennas should be adjusted far from the most potentially hazardous position with the surveyors approaching from out of the beam path toward the beam. Furthermore, if measurements are to be conducted while the antenna is scanning, (such as with an averaging module), one should first determine whether or not the response time of the instrument is fast enough to respond to the scanning beam.

A4.3.4.3. A theoretical examination of the radiation patterns should be made before beginning actual system operation or conducting the survey.

A4.3.4.4. Antennas should not be pointed toward metal structures, and metal objects should not be inadvertently located close to antennas. These not only create scattering and multipath situations, but are also a potential source of RF burns. However, if the normal area of transmission includes such metal objects, measurements should be conducted in those areas with the objects in place. The presence of secondary structures such as towers, guy wires, fences, reflecting surfaces, etc., can enhance the fields and produce RF hot spots. Allowance for such effects should be made when undertaking a survey. During the survey, the surveyor should be in continual communication with the operator of the RF source so that the source may be controlled according to survey requirements.

A4.3.5. Precautions During Leakage Surveys. When performing leakage surveys, the following precautions should be taken:

A4.3.5.1. The possibility of leakage exists at the site of the RF generator, along any transmission line or waveguide conveying power from the generator (particularly at waveguide joints), and at all access doors and panels that house the generator. Normally, leakage energy drops off rapidly with the inverse square of the distance. Therefore, the surveyor should begin at a safe distance (at least 3 feet) from the source. At this distance, the survey instrument may be set on the low range to aide the surveyor in detecting any signs of leakage. A slow approach toward the source keeping the meter under constant observation is the best way to detect the presence of any leakage while protecting the surveyor from the possibility of over-exposure. Care should be taken to avoid "pegging" the meter to full scale on the low range. If readings are present on the low range at a few feet from the source, then the surveyor should switch to a higher range before proceeding closure to the source.

A4.3.5.2. The possibility of RF burns exists, so contact should be avoided with any metallic structure on or near a point where high field strengths could exist.

A4.3.5.3. When operating access doors or panels to insert or remove a test load for example, in a microwave oven or RF-exposure test chamber), the equipment should shut down first and the interlock systems left operative.

A4.3.5.4. In checking for possible inoperative interlocks at an RF enclosure access port, one should ascertain leakage levels while the source is on and the port is closed. Then the surveyor may slowly open the port to observe any increase in leakage and possible interlock failure.

A4.3.5.5. Foreign objects (especially metallic objects) should not be inserted into any opening or port of the RF enclosure. This applies particularly in the case of high-power industrial systems that use conveyor belts carrying materials through ports of the RF enclosures.

A4.3.5.6. With the source switched off, the surveyor should visually inspect all flexible waveguides that carry high power. This inspection should determine signs of fatigue, aging damage at joints, and lack of adequate support, etc.

A4.4. Measurement Surveys- General Guidance.

A4.4.1. Evaluate the potential hazard of each emitter by the estimating procedures given in attachment 3, Calculations for RFR Hazard Evaluations. Then identify the capabilities and limitations of the instrumentation to be used for the field measurements. This is required to avoid unnecessary exposure to survey personnel and to prevent damage to instruments. Particular care must be taken to ensure that probe peak power limits are not exceeded since this will result in "burnout" of probe sensing elements. These are not field reparable and replacement is essentially the cost of a new probe.

A4.4.2. Since the power densities from multiple emitters are additive at any point where their fields overlap, it is essential that all emitters in the vicinity other than the one being measured, be shut down while initial measurements are made. Contributions from other emitters at the point of interest should be independently measured then added to make a set of isodose contours of the PEL distance. It may not always be possible to isolate each contributing antenna. In this case, measurement assistance from AL/OERS may be required.

A4.4.3. In addition to the main beam hazard, look for localized hot spots produced by reflections from or coupling of the beam or side lobes with metal surfaces and fences. These can occur in areas having general power densities less than the PEL.

A4.4.4. Certain fundamental actions must be taken at the time of the actual field measurements. These include:

A4.4.4.1. Complete and proper briefing of all personnel involved as to what is to be done and how it is to be accomplished, along with a definition of the possible hazards that may exist while the survey is in progress.

A4.4.4.2. Effective communications must exist between the operators of the emitter and survey personnel. Survey personnel must have absolute control over the emitter output, through the operators, at all times during the measurement procedure.

A4.4.4.3. Always begin measurements at a distance greater than the predicted PEL distance, which should be well known in advance.

A4.4.4.4. Survey personnel should avoid exposing themselves to the main beam or any other potentially hazardous field. Place instrument probes on non-conducting extensions where possible. Personnel exposure must not exceed the applicable PEL.

A4.5. Survey of Ground Based RF Emitters:

A4.5.1. These systems will generally bear "AN" nomenclatures, beginning with the letter F, M, G, or T, denoting the following types of systems (with examples):

Type:	**Example Nomenclatures:**
Fixed	AN/FPN-47, AN/FPS-90, AN/FRT-49
Mobile	MPN-14, MPS-9, MRC-113
Transportable	TPS-43, TRC-97, TPB-1B
Ground to Satellite	GSC-49

A4.5.2. Ground-mounted radar systems can sometimes operate in more than one mode. It is vital that all of the possible operating modes are considered during the presurvey evaluation to make sure that measurements are made with the system operating in the "worst case" mode for personnel exposures at the highest average power output and narrowest beam configuration).

A4.5.3. A visual inspection of the site should be made to determine if the main radiated beam is normally accessible to personnel. If it is not, radiation hazards to personnel should exist only in the area immediately surrounding the antenna. Remember that there could be modifications of either the emitter or the surroundings (cranes, mobile vans, construction work) that make the beam inaccessible.

A4.5.4. If the main beam is normally accessible to personnel, the antenna rotation (if applicable) must be stopped, and access to the main beam gained at a distance from the antenna determined during the presurvey. The beam size shape, and character should be determined, then the actual limit of the PEL located. From this beam stopped measurement, which represents a worst case situation, PEL distances for normal operations may be computed using equations provided in attachment 3. The best measurement technique when using isotropic survey meters, is to keep the probe handle parallel to the beam axis or perpendicular to the emitter surface as is proper, with probe and arm fully extended in front of the body. Try to avoid beam reflections from nearby objects.

A4.5.5. Whether the main beam is normally accessible or not, the area surrounding the antenna itself should be carefully surveyed for the existence of possible hazardous levels of energy. Also decide what personnel must do to gain access to areas having hazardous levels of energy and whether or not the controls in force are adequate to control access to such areas.

CAUTION: When surveying aperture type antennas, the area between the feedhorn and the reflector may contain very high power densities. Do not place any part of your body in this area. Also, power density levels in this area can easily damage survey instrument probes, so keep probes out of this area unless measured values absolutely must be obtained such as in the case of documenting actual exposure levels to a person.

A4.5.6. Operating personnel should be asked to accurately determine the actual power output value at the time measurements where made. Many ground systems have integral directional couplers and power meters available for this purpose.

A4.5.7. An inspection should be made to determine if the system being surveyed has adequate interlocks and to ascertain if the interlocks can be or are, in fact, regularly bypassed for routine maintenance or other purposes.

A4.5.8. A visual inspection should be made to determine if proper RF warning signs are posted in sufficient numbers and in the right places.

A4.5.9. Operating and maintenance personnel should be interviewed relative to their knowledge and understanding of the potential health hazards of radio frequency radiation. It is often possible to gain further insight by observing the activities of these personnel as they go about their normal duties.

A4.5.10. Technical Orders for each emitter being surveyed should be reviewed for the presence and adequacy of warnings to personnel regarding RF radiation. It should also be determined if written unit operating and accident reporting procedures have been established and are adequate.

A4.6. Survey of Airborne Radio Frequency Emitters.

A4.6.1. These systems usually begin with an A, such as, AN/APQ-120, AN/APN-59B, AN/ASG-19, AN/ASQ-42, etc. There are, however, a number of atypical nomenclatures, such as, MA-1, MD-9, R-14C, multimode, etc. During the presurvey phase of an evaluation, be certain that no emitters of interest are overlooked because of an atypical nomenclature.

A4.6.2. When aircraft systems are operated on the ground, the main beam is almost always accessible to personnel. The antennas of these systems, particularly radar antennas, are often at eye level and in normal operations, the main beam is often directed downward. Both operating and survey personnel must know of possible hazards prior to actual measurement being made.

A4.6.3. Airborne radar systems often operate in many different modes. Make sure that measurements are made with the system operating in the "worst-case" mode for personnel exposure. Usually, this would be the highest average power output and narrowest beam width. However, very narrow beams are sometimes difficult to locate during the measurement process, thus the beam dimensions, elevation, and azimuth locations must be known.

A4.6.4. When surveying airborne systems, position the aircraft with ample clear area in front of the antenna to preclude unnecessary radiation of other aircraft, vehicles, or buildings, where people may be present. The antenna should be stopped and positioned dead ahead in azimuth (boresited) and at zero degrees or slightly above in elevation. A zero or positive beam elevation is necessary to prevent reflections from the ground which can create unwanted, unpredictable, and possibly dangerous "hot-spots".

A4.6.5. The antenna should be approached from a known safe distance, and the main beam located. Once found, its size, shape, and other characteristics should be determined, and the isodose contour which corresponds to the PEL should be mapped. Care must be taken to maintain the probe along the main beam axis and the handle parallel to it. The actual value of power input to the antenna should be obtained from operators. Many airborne systems have integral directional couplers for this purpose.

A4.6.6. The area immediately surrounding the antenna (to the side and behind) should be surveyed for hazardous side lobes and back scatter. These are not commonly found. The area between the feedhorn and the reflector is very dangerous and should be avoided.

A4.6.7. It is desirable that a minimum of three different transmitters (three different aircraft) of a given type of emitter be surveyed to be sure that the values measured are truly representative of a given type of unit, and that a malfunctioning transmitter is not evaluated.

A4.6.8. During flight line measurements, observations should be made to determine if established procedures to protect personnel during routine ground operation of these systems are followed and are effective.

A4.7. In-shop (Avionics) Maintenance Operations.

The potential for RFR hazards to personnel in the repair and maintenance shops is very great. Most systems are operated only into dummy loads in the shops, but some require actual radiation through an antenna. Dummy loads should be evaluated to ensure the integrity of the system. Evaluation of antenna operations should be performed in the same manner that aircraft system measurements are performed, and should include a careful survey for possible reflection and scattering of radiation within the shop area. Sometimes, an RF absorber or anechoic chamber is used to shield personnel from antenna emissions. These operations should be surveyed to ensure the efficiency of the control device.

A4.7.1. The shop area should be inspected to make sure proper RF radiation warning signs (if appropriate) are posted in sufficient numbers and in the right places.

A4.7.2. Both operating and maintenance personnel should be interviewed relative to their knowledge and understanding of the potential health hazard of RF radiation. Again, it is helpful to observe their activities in both the shop and flightline environments.

A4.7.3. TOs for each emitter being evaluated should be reviewed for the presence and adequacy of warning to personnel regarding radio frequency hazards. Written unit operating and accident reporting procedures should be in effect and should be evaluated to determine adequacy.

A4.8. Survey of Medical RF Emitters.

The most common medical RF emitter is the diathermy machine. These units are usually located in the physical therapy section of USAF hospitals and clinics. Medical diathermy machines in the U.S. are authorized to operate on a number of frequencies. The most common frequencies used are 13.56 and 27.12 MHz (short wave diathermy) and 2450 MHz (microwave diathermy). Most units within the Air Force Medical Service operate on the two lower frequencies. A definitive study was made on Air Force diathermy units operating at these frequencies and copies of the report were sent to all USAF hospitals. More copies are available from AL/OERS upon request.

A4.8.1. The primary concern in evaluating diathermy units is NOT with the patient receiving treatment. It is assumed the therapy is being administered by or under the supervision of competent professional personnel. There is a significant potential hazard to the operators of this equipment, particularly from the S-band (2450 MHz) units. Evaluations must be made to be sure that therapists operate diathermy units in a way that will not cause them to be unnecessarily exposed, particularly to the head and shoulders. (***NOTE:*** The proper probes for measuring radiation from short wave diathermy units are not available at most bases.)

A4.9. Survey of Microwave Ovens.

Microwave ovens used for food preparation on Air Force installations do not require routine surveys regardless of the location of the oven. Ovens that are used on Air Force bases, or in the homes of military or civilian personnel assigned to the base, may be surveyed if the device is suspected to be leaking. Suspected leakage should be reported to PH and the oven removed from service until testing can be performed. PH will contact BE to conduct the field test and will provide the location and condition of ovens reported as leaking. Ovens found to be leaking in excess of 5 mW/cm2 at 5 cm from any point will not be returned to service until repairs are completed. BE must test all repaired ovens to ensure that the repairs were effective in preventing further leakage. If a field test is deemed necessary, the procedure should be accomplished according to the instructions provided in the paragraphs A4.9.1 through A4.9.1.3.2. BE will report leaking ovens to PH who will remove them from service and advise the owner/operator that repairs and retesting must be accomplished before the oven will be placed back into service. BE will prepare an annual report of findings that summarizes the results of all microwave oven surveys performed during that calendar year. Negative findings do not need to be reported. Only ovens that are found to be leaking in excess of 5 mW/cm^2 will be reported to the attention of Mr. Paul Leggett at the following address:

Food and Drug Administration, CDRH

Office of Compliance, HFZ 342

2098 Gaither Road

Rockville, Maryland 20857

Annual microwave oven field test reports must include the following information on each oven tested during the calendar year:

Field Test Results Narrative	Measurement Taken (mW/cm^2)
Suspected Cause of Leakage	Actions Taken (repaired, replaced or removed)
Manufacturer's Name and Address	Model Number
Date of Construction/Manufacture	Serial Number
FCC ID Number	Part Number

A4.9.1. Field Test Procedures. All test procedures should be done in the continuous power mode. Interlock tests should be done at the lowest continuous power setting and closed door tests at the highest power setting.

A4.9.1.1. Interlock Test (For Microwave Ovens with a DHEW Certification Label Affixed). Microwave ovens must have a minimum of two operable safety interlocks plus a monitoring circuit. Leakage measurements must be made with the door fully closed, as well as with the door fixed in any other position which allows the oven to operate. Thus, as one is opening the door, the leakage limits must not be exceeded. This places a requirement upon the first of the two interlocks--to turn the oven off before the leakage limit is exceeded. Most ovens manufactured after October 6, 1971, have a latch interlock that should turn the oven off before any door movement begins. The following procedures will test first for a major failure of the interlocks and then for a more subtle malfunction with the door in a fixed position.

A4.9.1.1.1. Place an electrically nonconductive (glass or plastic) 600 ml beaker (having an inside diameter of 8.5 cm) containing 275 ml $\pm$ 15 ml of water initially at 20 degrees + 5 degrees centigrade in the center of the oven cavity. This is referred to as the standard water load. Open the door about 2.5 cm and try to turn on the microwave oven. If the oven should come on, stop the test immediately by closing the door. Show on the survey form whether or not the oven operated with the door opened 2.5 cm.

A4.9.1.1.2. To perform an interlock test on a microwave oven with a latch interlock, turn on the oven with the standard water load in place. If it does not turn off as the latch is activated, record a failure under the remarks section of FDA Form 2536.

A4.9.1.1.3. If possible, perform a slow door opening test as follows: Place the standard water load in the oven, turn the oven on, and measure microwave leakage while slowly opening the door. The probe should be at a position opposite the hinges where maximum door movement takes place or at any other point where maximum leakage is detected. The leakage should be carefully monitored as the door is slowly opened, and the oven should turn off before leakage exceeds 5 mW/cm^2. Record the leakage measured under the remarks section of FDA Form 2536.

A4.9.1.2. Interlock Test (for ovens without a DHEW certification label). On ovens that are not certified to comply with the microwave oven product performance standard, it is more difficult to perform the interlock tests. Some models of ovens can emit a high burst of microwave leakage as the door is being opened. Sufficiently high bursts can easily burn out the white probe of a Narda System. Exercise caution when following these measurement procedures.

A4.9.1.3. Closed-Door Leakage Test (Microwave Measurement):

A4.9.1.3.1. Place the standard water load on the center of the load bearing surface of the oven. The standard load is important as it protects the oven and allows leakage to be measured accurately.

A4.9.1.3.2. If the power level of the oven is selectable, choose the setting for a maximum power output. Most ovens have only one power setting, but several buttons for varying the on time. Some ovens offer a choice of power levels. Close the door and turn the oven on with the timer set for several minutes. If the water begins to boil before the survey is completed, replace it with cool water.

A4.9.1.3.3. If the instrument has a meter response switch, set it to the fast position. Hold the probe of the surveying instrument perpendicular to the crack between the door and the body of the oven. Move the probe slowly along the crack, watching for the maximum indication on the meter. Reset the timer and replace the water load, if necessary, and check for leakage at the door screen, sheet metal seams, and any other accessible position where there is a break or opening in the oven cabinet such as around the switches, indicator lights, and vents.

A4.9.1.3.4. If the instrument has a meter response switch, set it to the "slow" position. Measure carefully at the point of highest leakage and record the power density to the nearest 0.1 mW/cm^2. Determine which surface of the oven displayed the maximum leakage reading and circle the appropriate number on the form; for example, for the right side, circle 5. Next describe the location of the leakage on that surface by circling a number corresponding to the point of highest leakage. If the oven door is flush with one side and this is where the leakage occurs, the seal should be considered as part of a side rather than the front.

A4.9.1.4. Intrusion Test. Look for a straight, unobstructed line of sight into the oven cavity. If one exists, record this observation under the remarks section of FDA Form 2536 and treat the oven as having failed the intrusion test (e.g. remove from service until the defect is corrected). Do not try to insert anything into the oven cavity through any opening, as you may create an electrical shock hazard.

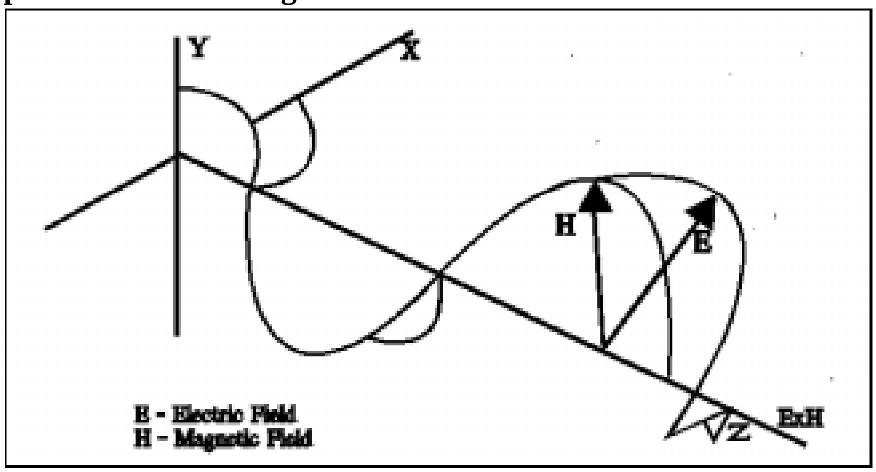
Attachment 5

INTRODUCTION TO RADIO FREQUENCY RADIATION AND BIOEFFECTS

A5.1. Nature of Electromagnetic Radiation.

A5.1.1. Electrical energy emitted into free space exists in the form of electromagnetic waves. These waves travel with the speed of light and consist of magnetic and electric fields at right angles to each other and, also at right angles to the direction of travel. If these electric and magnetic fields could actually be seen, the wave would have the appearance indicated in figure A5.1.

Figure A5.1. Properties of Electromagnetic Waves.



A5.1.2. The essential properties of a wave are the frequency, intensity, direction of travel, and polarization. The waves produced by an alternating current will vary with the current and, therefore, be alternating positive and negative as shown in figure A5.1.

A5.1.2.1. The distance occupied by one complete cycle of such an alternating wave is equal to the speed of the wave divided by the number of cycles that are sent out each second and is called the wavelength. The relationship between wavelength λ in meters and frequency in hertz (Hz) is therefore:

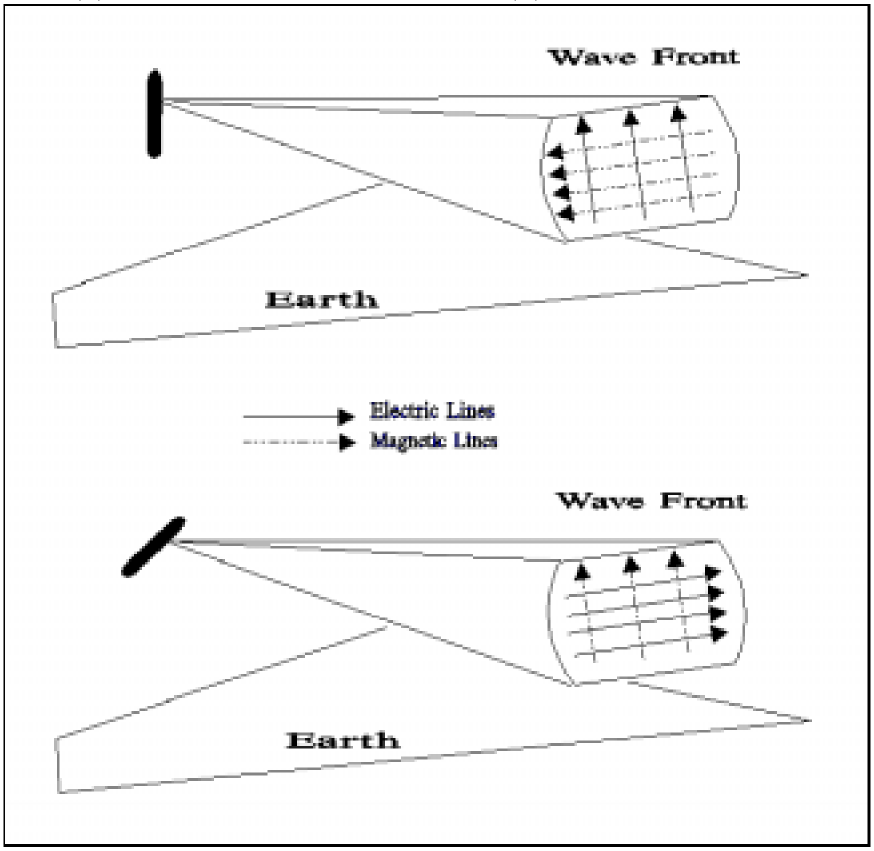
$$\lambda = \frac{300{,}000{,}000}{f}$$

The quantity of 300,000,000 is the speed of electromagnetic propagation (speed of light) in meters per second. A low-frequency wave has a long wavelength, while a high-frequency wave has a short wavelength.

A5.1.3. The intensity of a wave is determined by the strength of its electric and magnetic field components. The electric field strength (E) is usually given in volts per meter (V/m), and the magnetic field strength (H) is given in amperes per meter A/m).

A5.1.4. A plane parallel to the mutually perpendicular lines of the electric and magnetic fields is called the wave front. As shown in figure A5.2a, the wave always travels in a direction at right angles to the wavefront, but whether it goes forward or backward depends upon the relative direction of the lines of magnetic and electric field. If the direction of either the magnetic or electric field is reversed, the direction of travel is reversed, but reversing both sets of fields has no effect.

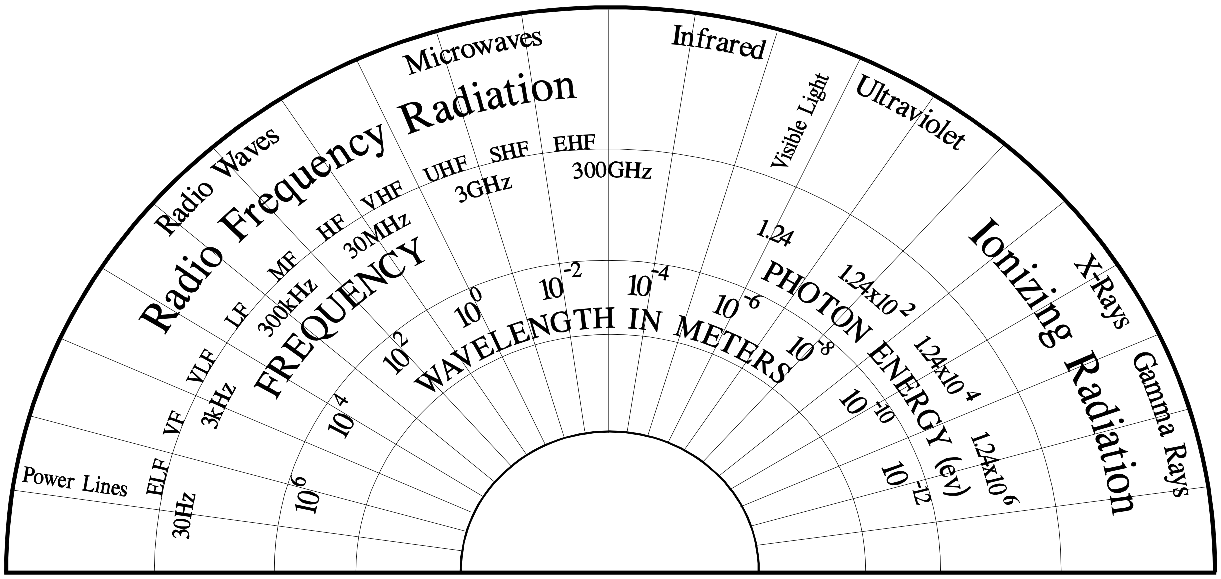
Figure A5.2. Vertical (a) and Horizontal Polarization (b).



A5.1.5. The direction of the electric field lines is called the direction of polarization of the wave. If the electric field lines are horizontal, as shown in figure A5.2b, the wave is horizontally polarized; if the electric field lines are vertical and the magnetic field lines are horizontal, the wave is vertically polarized (figure A5.2a). Elliptical polarization is characterized by the fact that the resultant magnetic (or electric) fields produced by an alternating wave never, at any instant, pass through zero; rather the resultant fields rotate in the plane of the front at a rate corresponding to the frequency of the wave, while at the same time pulsating in amplitude. The resultant field produced by elliptical polarization can, therefore, be represented by a rotating vector of varying length. The field can never be zero because the vertical and horizontal components do not pass through zero at the same instant.

A5.1.6. Figure A5.3 gives the electromagnetic frequency spectrum and shows some of its specific applications and properties. The RF portion of the spectrum is contained within this broad spectrum of frequencies and is defined as that segment between 10 kHz and 300 GHz. Conventional RF band designations may be found in TO 31Z-10-4. Electronic Countermeasures (ECM designations are listed in AFR 55-44).

Figure A5.3. Electromagnetic Spectrum.



A5.2. Production of Radio Frequency Radiation Fields:

A5.2.1. Electromagnetic radiation is produced whenever a conductor carries an alternating current. Some common sources of electromagnetic radiation are: microwave ovens, diathermy, radar, television radio communications, and microwave data link transmission. The laws governing such radiation are obtained using the four fundamental expressions of electromagnetism (Maxwell's equations) which are valid for all media. When these laws are used to express the fields associated with the conductor, there is an electric and magnetic component, termed the radiated field, which varies inversely with distance from the source.

A5.2.2. The electric and magnetic fields in the immediate vicinity of an antenna (near field) are greater in magnitude and different in phase from the radiated fields (far fields). The electric and magnetic fields that must be added to the radiated fields, in order to give the fields actually present, are termed induction fields. These induction fields diminish in strength more rapidly than in inverse proportion to distance. At distances of a few wavelengths they become negligible in comparison with the radiated fields. However, at distances from the antenna that are small compared with a wavelength (or small compared with the antenna dimensions if the antenna is large), the induction electric and magnetic fields will be much stronger than the radiated fields of the antenna.

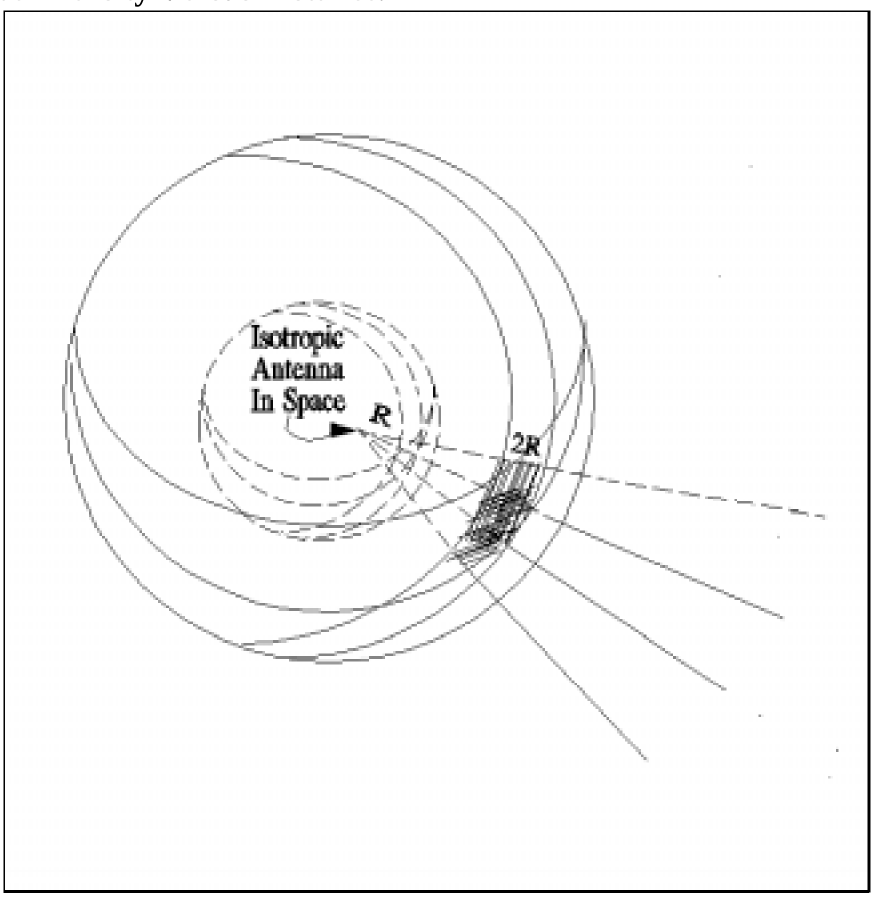
A5.2.3. The three broad classes of antennas are aperture, directional wire, and omnidirectional. An aperture antenna is one from which essentially all of the radiation emanates from an aperture. Usually a feedhorn illuminates a reflecting surface which concentrates the RF energy into a small, highly directional beam. This results in the antenna having a power gain relative to an omni or nondirectional antenna. The beam widths produced by aperture antennas may be as small as 0.1 degree in both azimuth and elevation. Directional wire antennas such as the helix, the yagi, the log periodic, or the rhombic, have broad directional characteristics and much lower power gains than aperture antennas. Omni-directional antennas such as the vertical ship, dipole, or inverted vee have low power gain.

A5.2.4. RF radiation can be reflected in a manner similar to light, and under the same condition that the physical dimension of the reflector must be large compared to the wavelength reflected. Metallic reflecting surfaces in the shape of a parabolic, spherical, or cylindrical surface may be used to direct a beam of energy in a manner similar to an automobile head lamp. This type of beam transmission finds most use at ultra high frequencies (0.3-3 GHz) where the dimensions of the radiating elements are small. By using two or more antennas properly spaced and phased in an array, directional transmission can be realized by causing the radiated signals to add in the preferred direction and to cancel in others.

A5.2.5. The directive gain of an antenna is defined as the ratio of the power density that is radiated in the preferred direction to the radiated power density averaged over all directions. This can be expressed either as a power density ratio (numerical gain) or in terms of decibels.

A5.2.6. The decibel (abbreviated dB is a logarithmic unit used to express power ratios. If the powers being compared are P_1 and P_2 , then $dB = 10\log_{10} P_2/P_1$

Figure A5.4. Power Density Versus Distance.



A5.2.7. The electromagnetic wave spreads out so that the intensity of the radiated energy (power density) in the far field region varies inversely as the square of the distance. The relationship between power density and distance is illustrated in figure A5.4, which shows part of the pattern of radiated energy from an isotropic antenna. An ideal isotropic antenna distributes its radiated energy uniformly in all directions. Imagine a sphere of radius R (surface area = $4\pi R^2$) with the antenna at its center. The fraction of the total power which passes through the unit area A on the surface of the sphere is

$P_A/P_T = A./4\pi R^2$ and the power density at any point on this sphere is $PD_{R} = P_a / A = P_T/4\pi R^2$

The figure shows that at distance 2R from the source, the same fraction of the total power is projected in an area four times as great, so that the power density is decreased by a factor of four. Similarly, at distance 3R, the power density will have decreased by a factor of nine. The power density from a source, then, decreases in proportion to the square of the distance from the source.

A5.3. Characteristics of Radiofrequency Applications:

A5.3.1. It is possible to convey information by modulating any property of a carrier wave. These properties are amplitude, frequency, and phase. Amplitude modulation (AM) is done by varying the output power of the transmitter in accordance with the modulating signal. Pulse modulation (used in telemetry and radar systems) is a special form of amplitude modulation. When the frequency of the carrier wave is varied in accordance with variations in modulating signal, the result is frequency modulation (FM). Similarly varying the phase of the carrier current is called phase modulation (PM).

A5.3.2. For AM, 100 percent modulation, the average power will equal a maximum of 1.5 times the unmodulated carried power. For pulse modulation, the average power is equal to the product of peak power and duty factor (DF), where DF = pulse width in units of time (PW) x pulse repetition frequency (PRF). For FM and PM the average power can be considered equal to the peak power.

A5.4. Electromagnetic Pulse:

A5.4.1. Nuclear explosions produce a short, intense electromagnetic pulse (EMP) which, depending on the altitude, can radiate over many hundreds of miles. This pulse is produced by a flow of Compton electrons generated in the atmosphere as the front of gamma rays from the burst interacts with the air molecules. The restrictions on atmospheric nuclear testing have made it necessary to construct EMP simulators for the empirical investigation of EMP interaction and effects on military hardware.

A5.4.2. While available EMP data suggest that no acute or chronic bioeffects can be assigned to EMP exposure, tentative limits are established in this standard as a precautionary measure.

A5.5. Biological Effects of Radiofrequency Radiation.

A5.5.1. Introduction. Induction of heat in biologic tissue by RF radiation has been known for more than 80 years. This fact has been the basis of RF diathermy as used in the practice of physical therapy. Energy from the RF field is transferred to tissue by increasing the rotational energy of dipoles in the tissue. The principal dipole in biologic material, the water molecule, has the property of high viscosity (or long relaxation time). This makes it a very good absorber of RF energy. Changes result from the absorption of energy which may, or may not, produce temperature increases; however, the underlying mechanisms are basically driven by thermodynamic principles and the physiological responses thereto. There has been a substantial increase in research regarding the biologic effects of RF radiation and a great deal has been learned about the absorption and distribution of RF energy in biologic material and the resulting physiological consequences.

A5.5.2. Absorption of RF Radiation.

A5.5.2.1. The absorption of RF energy by biologic materials is strongly influenced by the frequency of the incident radiation and by the orientation of the object in the electromagnetic field. Using prolate spheroids, ellipsoids, and scaled models of man, studies have shown that whole-body absorption of RF energy is very strongly dependent upon the orientation of the long axis of the body relative to the electric field. Furthermore, the greatest absorption in this orientation occurs when the body length is approximately 0.4 of the free-space wavelength. This optimal absorption occurs at frequencies of about 70-80 MHz for adult humans. These frequencies are termed "resonant frequencies". When a person is in perfect ground contact, the resonant frequencies will shift to 35-40 MHz. A small separation from ground, e.g., wearing shoes, in most cases returns the resonant frequency to free-space conditions (70-80 MHz).

A5.5.2.2. The concept of a specific absorption rate (SAR) was developed to facilitate comparison of exposure conditions from experiment to experiment and from experiment to man. The SAR is the mass normalized rate of RF energy absorbed under different exposure conditions and/or for different frequencies. The SAR concept has been particularly useful for the extrapolation of experimental data from animals to man. It is possible to equate the SAR at a particular frequency and power density required to produce a discrete bioeffect in an experimental animal to the frequency and power density required to produce that same SAR in man. SAR's are given in units of watts per kilogram (W/kg).

A5.5.3. Biological Effects. The preponderance of studies reported to date have not defined any deleterious health effects from exposure to RF energy below a SAR of 4W/kg. Studies that have been reported which show effects below a SAR of 4W/kg either report effects which are not considered hazardous, or effects which have not been substantiated by replication in other laboratories. Extensive research continues in order to establish the validity and true nature of these effects. SAM-TR-87-03 provides a critique and summary of the relevant RF bioeffects literature to date, and is periodically updated to maintain currency with the extensive research underway in the world today.

A5.5.3.1. Athermal Effects. An important point to get across when discussing the effects of RF energy, is that biological effects are not necessarily hazards. Research communities throughout the world continue to publish paper after paper on the biological effects of RF Radiation. Some scientists have reported long lists of symptoms at levels of exposure that are well below the PEL. Some recent studies indicate a normal response in nerve cell tissues may be triggered by long term exposure to low levels of RF energy. All efforts to replicate such results have failed. Epidemiological studies conducted by various communities have attempted to correlate exposures to extremely low frequencies to childhood leukemia. Yet, epidemiological studies conducted by the Navy on radar technicians indicated no increase in the risk of cancer. The fact is, there is so much controversy in the scientific community surrounding these alleged effects that we cannot totally ignore them. The Air Force is not discounting the remote possibility of the “athermal” effects, but these still appear to be effects that may be observable under laboratory conditions, but have not demonstrated the potential to cause harm. Furthermore, these effects cannot be substantiated by leading Air Force, industry, or academic scientists. Certainly, not enough data has been collected to establish a set of standards based upon observed athermal effects. Therefore, the current US Air

Force standard for RF Radiation protection, is designed to protect personnel from known thermal hazards associated with RFR emissions.

A5.5.3.2. Direct Biological Effects. RFR energy at sufficiently high levels causes heating in body tissues. The amount of RFR energy that is absorbed and converted to molecular energy is strongly frequency dependent. Generally, it can be said that the longer the wavelength the greater the depth of penetration. Wavelengths of 3 cm or less (10 GHz or higher) are absorbed by the skin. Depth of penetration is only one factor; energy deposited is the key issue. The mechanism for transfer of energy to the human body by RFR is by friction resulting from the vibration/rotation of the body's polar molecules (mainly water) within the viscous cell membrane. Regardless of frequency, an RFR induced thermal burden adds to other thermal burdens and produces normal physiological adjustments like sweating and vasodilation. If effective dissipation of heat is prevented by biological or environmental factors, the exposed tissue will be heated and possibly damaged. The effects of this type of exposure are not considered to be cumulative as they are with ionizing radiation. Exposures separated by more than a few minutes (6 by the standard) are essentially separate physiological events.

A5.5.3.2.1. Microwave Hearing Effect. The so-called "microwave hearing effect" has been known for more than 30 years and consists of an audible sound which seems to originate within or near the head. The sensation is described as clicking, buzzing, or chirping sound depending upon the pulse repetition rate and pulse width of the incident RF radiation. The mechanism responsible for the sensation is similar to that produced by ordinary sound. The pulses of RF energy appear to produce a thermoelastic wave or pressure wave described as a cochlear microphonic. This wave is conducted by inner ear structures to receptors, and then by nerve impulses to the brain as in ordinary sound perception. For 15 microsecond pulses the threshold for this response is approximately 700 mW/cm2. Most operational systems will not produce power densities in accessible locations that reach this threshold. This effect, of itself, is not considered to be hazardous. However, any reports of this effect should be treated as a possible overexposure and carefully investigated.

A5.5.3.2.2. Ophthalmologic Considerations. RF energy has been shown to produce cataracts in experimental animals when the exposure is sufficient to raise the temperature of the lens to around 41 degrees Celsius. Localized exposure experiments in rabbits, exposure for 1 hour to 2450 MHz radiation at 100 mW/cm2 is sufficient to induce a cataract. However, these experiments would produce burns to the skin tissue surrounding the eye before a cataract would form. Whole body exposures did not produce the same results as localized exposures to the eyes, because the animal would expire before the end of the experiment.

A5.5.3.3. Indirect Biological Effects:

A5.5.3.3.1. Electronic medical prosthetic devices such as artificial cardiac pacemakers can respond to pulsed RF radiation fields. Significant disruption of normal pacemaker function requires RF radiation signals having a primary frequency between 0.1 and 5 GHz, pulse widths of greater than 10 microseconds, and electric field strengths greater than 200 V/m. Access to areas where these parameters and field strengths are used is restricted. However, it is prudent for individuals dependent on such devices to recognize the possibility of interference and avoid controlled areas.

A5.5.3.3.2. Metal Implants. Little is known concerning the interaction of RF radiation with metal implants such as cranial plates or orthopedic pins. However, it is thought that PELs in this standard provide adequate protection against harmful effects from any interaction with such implants, and no instances of adverse reaction to RF fields from metal implants have been reported.

A5.5.3.4. Conclusion. The PELs given in this standard are the result of extensive scientific research on the characteristics of RF radiation interactions with living organisms. The frequency dependent interactions of RF radiation with geometric and biological objects, including humans, have been published in the "Radiofrequency Radiation Dosimetry Handbook", SAM TR-85-73. Data in this handbook can be used to determine the incident power density as a function of frequency to limit whole body SARs to 0.4 W/kg or less and may also be used to extrapolate exposures causing effects in animals to those in man required to produce the same SAR.

Attachment 6

RECOMMENDED MEDICAL SURVEILLANCE PROCEDURES

A6.1. Occupational Medicine.

Routine pre-placement, baseline, periodic and termination occupational medical examinations are not required. There is no known scientific or epidemiological basis to support such requirements. Bioeffects research and epidemiological studies indicate that ocular effects, such as the formation of cataracts, are a threshold phenomenon occurring during localized exposures to levels more than 10 to 100 times the permissible exposure limits. These effects are not distinguishable from those caused by aging and other physiological events; and have not been demonstrated conclusively in humans exposed at levels below the current PEL. Individuals who are allegedly exposed to levels above the PEL will receive extensive medical testing/examination or eye examinations as indicated only under the following conditions:

Condition 1: The symptoms displayed at the time of the initial, cursory examination (within 72 hours following exposure) indicate the need for further testing and/or examination, as determined by the attending physician. All symptoms noted should be treated and followed-up within 72 hours following exposure.

Condition 2: The BE determines that the patient was overexposed to at least 5 times the PEL Eye examinations should be accomplished within 72 hours following the incident if the exposure involved the patient's eyes.

Condition 3: The patient was exposed to an undetermined amount of RF energy, but was definitely exposed above the existing time-weighted average PEL, and the exposure was localized to the head and may have involved the eyes.

Condition 4: The patient allegedly exposed insists that he/she experienced some physical phenomenon that was not detectable during initial, cursory examination and the BE finds that the individual was exposed to levels exceeding the PEL. ***NOTE:*** Any suspected exposure to RFR will be investigated by the BE. If the investigation finds that the individual's exposure was below the PEL, then the patient must be clearly advised and the findings of the investigation must be documented in his/her medical records and the industrial facility case file which is maintained by BE.

A6.2. Examination Checklist. The following checklist should be used to ensure that nothing is overlooked during initial medical response to the concerns of a patient who is alleging personal overexposure to RF radiation:

I. HISTORY:

- a. Present Illness. Include the following information:
    1. Type of Equipment, Model Number, and Frequency.
    2. Distance from the source to the person.
    3. Exposure Duration.
    4. If intermittent give longest individual time exposed and overall time period.
    5. Were any noises heard in the ears?
    6. Was a sensation of heat experienced - where?

7. What body part(s) believed to be involved.
8. Does a previous history of RFR overexposure exist?
9. Does a previous history of other overexposure (chemical or physical agents) exist?

b. Past Medical History

1. List all types of occupations not just Air Force.
2. Obtain standard past medical history.

c. Complete Review of Systems

II. Physical Examination: Eyes and skin are primary interest. The signs to look for are cataracts and burns.

a. Eyes. Describe the condition of the skin around the eyes as well as the eye itself. Slit Lamp examination should be done as soon as practicable. If any question is raised due to the slit lamp exam, refer patient to an ophthalmologist for dilated slit lamp examination.

b. Skin. Observe for signs of heat-induced change and electrical burn. Note findings, even negative ones.

III. Laboratory Studies: These should be as indicated. No single test has any particular virtue. Routine Tests, if done should be limited to CBC and UA. Any others should be done for clinical reasons.

IV. Referral: As clinically indicated through the normal channels.

V. Special Cautions:

a. Patient anxiety due to assault by an invisible agent. They are usually unfamiliar with the possible results of an overexposure and often have filled in the blanks with generalized fears of cancer, birth defects, and sterility. Unless there is an obvious connection between a finding and the exposure, other than a temporal one, the exposure and the finding are probably not connected. If you don't know, say so, but try to find out to put the patient's fears to rest.

b. Epidemiological studies to date have not demonstrated any long term consequences beyond those present at the time of the exposure.